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CONTENTS

Upper Cretaceous Mollusca from Southern California ..... *Willis Parkison Popenoe* 379

A New Pennsylvanian Cephalopod Fauna from Oklahoma ..... *A. K. Miller and John Britts Owen* 403

The Lower Middle Devonian Tetracorals of the Nevada Limestone *Erwin C. Stumm* 423

The Genus *Cynarctus* ..... *Paul O. McGrew* 444

Euceratherium bizzelli, a New Ungulate from Oklahoma ..... *J. Willis Stovall* 450

PALEONTOLOGICAL NOTES

The Genotype of *Mortoniceras* Meek ..... *T. W. Stanton* 456

Note on the Crystallography of the Echinoderm skeleton ..... *C. D. West* 458

Notes on the Craniometry of *Equus scotti* Gidley ..... *C. Stuart Johnston* 459

A study of *Neuropteris schlehani* Stur ..... *Lou Williams* 462

SOCIETY RECORDS AND ACTIVITIES

Paleontological Society: Officers and Members 466

ERRATUM 476

JOURNAL of PALEONTOLOGY

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VOLUME 11 JULY, 1937 NUMBER 5

CONTENTS

PAGE

Upper Cretaceous Mollusca from Southern California . . . . . *Willis Parkison Popenoe* 379

New Pennsylvanian Cephalopod Fauna from Oklahoma . . . . . *A. K. Miller and John Britts Owen* 403

The Lower Middle Devonian Tetracorals of the Nevada Limestone . . . . . *Erwin C. Stumm* 423

The Genus *Cynarctus* . . . . . *Paul O. McGrew* 444

Eucratherium bizzelli, a New Ungulate from Oklahoma . . . . . *J. Willis Stovall* 450

PALEONTOLOGICAL NOTES

The Genotype of *Mortoniceras* Meek . . . . *T. W. Stanton* 456

Note on the Crystallography of the Echinoderm skeleton . . . . . *C. D. West* 458

Notes on the Craniometry of *Equus scotti* Gidley . . . . . *C. Stuart Johnston* 459

A study of *Neuropteris schlehani* Stur . . . . *Lou Williams* 462

SOCIETY RECORDS AND ACTIVITIES

Paleontological Society: Officers and Members 466

ERRATUM 476

JOURNAL OF PALEONTOLOGY, VOL. 11, NO. 5, PP. 379–402, PLS. 45–49, JULY, 1937

UPPER CRETACEOUS MOLLUSCA FROM SOUTHERN CALIFORNIA

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California Institute of Technology
Pasadena, California

ABSTRACT

One new genus and thirteen new species of Mollusca are described from the Upper Cretaceous fauna of the Santa Ana Mountains, southern California. New generic assignments based upon discovery and study of previously unobserved structural features are offered for a number of common and well-known Cretaceous molluscan species. Some genera hitherto unknown in the Upper Cretaceous of the Pacific Coast are recognized, and their affinities are discussed.

In this paper are described and figured thirteen new species and one new genus of Upper Cretaceous Mollusca from the Santa Ana Mountains, southern California. In addition there are presented notes on the dentition and systematic relationships of a number of Upper Cretaceous Mollusca that were described many years ago but that until now have been imperfectly known. For each form discussed is given the stratigraphic range in the Upper Cretaceous beds of the Santa Ana Mountains. Such observations upon the relationships of these forms and of the occurrence of allied species as have seemed pertinent are included in the discussions. The synonymies of previously described species list only those references in which the species has been described, figured, or discussed, omitting citations in fossil lists. Genotypes are cited for genera not previously recognized in the Upper Cretaceous of the Pacific Coast.

In the course of the study of which a part of the results has been included in this paper, I have benefited from the helpful advice of Dr. J. P. Buwalda and Dr. Chester Stock, of the Division of Geological Sciences, California Institute of Technology. Dr. L. W. Stephenson, Dr. J. B. Reeside, Jr., and Dr. Ralph Stewart, of the United States Geological Survey, have given me much assistance in the determination of the systematic positions and relationships of a number of the fossil species herein discussed and have made helpful suggestions many times in the course of the work.

Dr. B. N. Moore, of the United States Geological Survey, has given me free use of the collections of Cretaceous fossils he made some years ago in the Santa Ana Mountains. Dr. A. Myra Keen, of Stanford University, has studied the specimens of *Pachycardium coronaense* discussed in this report and has given me valuable advice as to their relationships and systematic position. The authorities in charge of the paleontological museums of the United States National Museum, the California Academy of Sciences, the

Leland Stanford Junior University, and the University of California have been most courteous and helpful in making the facilities and collections in their charge available to me. I am glad to acknowledge the aid I have had from each of these sources.

The generalized section is given below of the stratigraphic subdivisions of the Upper Cretaceous sedimentary rocks of the Santa Ana Mountains as recognized in this paper.

Numbers in parentheses following citations in the discussions of species refer to the numbered references at the end of this paper. Where more than one citation has been made from any one reference the page number is included in the parentheses, following the reference number.

Generalized section of formations in the Santa Ana Mountains, California

Eocene.

Martinez? formation: Prevailingly light-colored coarse sandstone, conglomerates, and shale, with some coal seams. In part marine.

Unconformity.

Upper Cretaceous.

Williams formation:

Pleasants member: Light-colored shaly sandstones with many beds of limy fossiliferous sandstone intercalated. Approximate thickness, 320 feet.

Schulz member: Light-colored, coarse, arkosic sandstones with numerous beds of well-rounded boulders. Unfossiliferous. Average thickness, 200 feet.

Unconformity.

Ladd formation:

Holz member: Dark bluish- to brownish-gray micaceous sandy shale or siltstone, with interbedded arkosic sandstones and nonpersistent coarse conglomerate lenses. Fossiliferous in the upper half. Thickness, 1,500 feet ±.

Baker member: Gray to brownish, massive to thick-bedded boulder conglomerate below, grading up into thick-bedded to shaly arkosic soft brown sandstone above. Sandstones at top highly fossiliferous. Thickness, 200 feet ±.

Cretaceous?

Trabuco formation: Soft red friable deeply weathered massive boulder conglomerate. Un fossiliferous. Thickness, 300–400 feet.

Unconformity.

Pre-Cretaceous.

Basement complex: Metamorphosed sediments intruded by andesitic dikes and stocks.

SYSTEMATIC DESCRIPTIONS

Class PELECYPODA
Order PRIONODESMACEA
Family LIMOPSIDAE

Genus TRINACRIA Mayer

Genotype: *Trigonocoelia crassa* Deshayes.

TRINACRIA COR Popenoe, n. sp.
Plate 45, figures 1–3

Description: Shell large and massive for the genus, high, short, angular; beaks small, sharply incurved, opisthogyrous; dorsal anterior margin concave directly in front of the beaks, merging thence into the tumid anterior margin; ventral margin nearly straight; posterior margin abruptly truncate immediately back of the beaks, separated from the lateral portions of the shell by an abrupt umbonal angulation; lateral and ventral surfaces of the shell meeting at nearly a right angle; posterior shell surface back of the angulation nearly flat; sculpture of fine

growth lines with occasional deeper incised concentric grooves marking resting stages of growth; very fine rather widely spaced radial lines appear on well-preserved specimens; area short, amphidetic, shallow, directly beneath the beaks; dentition of about five minute chevron-shaped teeth on each side of the beak; muscle scars and pallial line unknown.

Holotype: California Inst. Technology, Invertebrate Paleo. Cat. no. 3418.

Dimensions of holotype: Length, 16.0 mm., height, 14.0 mm., thickness of one valve, 6.4 mm.

Distribution: Holz shale member, *common;* Williams formation, *common.*

Discussion: This species is also found in the Upper Cretaceous of the Simi Hills and of the Santa Monica Mountains, southern California, and also in the "type Chico" beds of Chico Creek, Butte County, California.

One other species of *Trinacria* (*T. galeata*) has been described from Cretaceous beds by Holzapfel (11, p. 213), but the genus is most numerous in the Eocene beds of the Paris Basin and of Alabama. *Trinacria* has been reported from the Oligocene of Washington by Clark (5, p. 81), and from the Miocene Alum Bluff group of Florida by Dall (7), and Gardner (10), but Stewart (18, p. 82) has questioned the reference of these species to *Trinacria*. If these references be incorrect, the known range of the genus is Upper Cretaceous and Eocene.

Trinacria cor is larger and more massive than any other member of the genus known to me, and it is also distinguished by its abruptly truncated posterior border and by its high beaks.

Family LIMIDAE

Genus LIMA Bruguiere
Subgenus LIMATULA Wood

LIMA (LIMATULA) sp. cf. L. SUCIENSIS Whiteaves
Plate 45, figure 4

Description: Shell small, thin, slightly inequilateral, rather more high than broad, outline gibbous; anterior dorsal slope shallowly concave from the umbo to about one-half the distance from the umbo to the ventral border; ears approximately equal, small; beaks low and pointed; sculpture on the posterior half of the shell consisting of very fine radiating ribs crossed by fine growth lines, producing a minute cancellation; sculpture of the anterior portion of the shell of low smooth sharp-crested ridges separated by interspaces several times wider than the ridges; anterior dorsal slope unornamented except for growth lines.

Dimensions of figured specimen: Height, 18.0 mm., length, 17.2 mm., thickness of one valve, approximately 4.0 mm.

Distribution: Ladd formation, Baker member, *rare.*

Discussion: The subgenus *Limatula* to which this species is referred includes straight or slightly oblique forms with pronounced sculpture on the middle part of the valve, but with the posterior and anterior slopes of the valves only slightly sculptured, or smooth.

This *Lima* agrees fairly well in outline and in size with Whiteaves' figure of *L. suciensis* (20, p. 399, pl. 51, fig. 2) and may be conspecific with it. Whiteaves' description includes these remarks:

> Surface markings consist of small narrow radiating ribs that are everywhere crossed by concentric striae or lines of growth. From eleven to fourteen of these ribs are a little larger than the rest, and in testiferous specimens, the spaces between them when examined with a lens are seen to be occupied by from four to six close-set minute radiating ridges.

These features suggest the subgeneric characters of *Limatula*, but unfortunately Whiteaves' figure of the species is not sufficiently good to determine the characters of the shell accurately.

Apparently no other described species of *Lima* from the Pacific Coast Cretaceous is likely to be confused with that from the Santa Ana Mountains.

Subgenus ACESTA H. and A. Adams

LIMA (ACESTA) BETA Popenoe, n. sp.
Plate 45, figure 5

Description: Shell moderately large, thin, fragile, pyriform, slightly convex; beaks low; anterior margin nearly straight, excavated dorsally; anterior ear very slightly developed; posterior and ventral margins forming a sweeping regular curve; posterior ear small, obliquely truncate; sculpture consisting of narrow radiating ribs toothed on the crests and separated from one another by concave interspaces three to four times wider than the ribs; interrib areas ornamented only by fine growth lines; resilium pit oblique, directed toward the posterior side.

Holotype: California Inst. Technology Invert. Paleo. Cat. no. 3424.

Dimensions of holotype: Height, 35.3 mm., length, 27.3 mm., thickness of one valve, approximately 5.0 mm.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic.*

Discussion: The subgenus *Acesta* to which this species is referred includes Limas with straight anterior margins, small to obsolete anterior ears, and with oblique ligament pits extending under the posterior ear.

Among other West Coast Cretaceous Limas, only *L. microtis* Gabb appears to resemble *L. beta.* In his diagnosis of *L. microtis,* Gabb (9, p. 202) remarks:

> Ornamented by numerous flat radiating ribs, not dichotomous, the interspaces forming shallow grooves serrated on the sides and marked in the middle by a series of small pits or punctations.

In contrast to this description, the ribs of *L. beta* are sharp-crested and denticulate on top. No sign of punctations or serrations appears on the interspaces.

Family MYTILIDAE Fleming

Genus INOPERNA Conrad

Genotype: *Inoperna carolinensis* Conrad.

INOPERNA BELLARUGOSA Popenoe, n. sp.
Plate 45, figures 6, 7

Description: Shell of moderate size, elongate, compressed, gently concave on the ventral and convex on the dorsal margins, margins diverging slightly posteriorly; beaks low and small, markedly anterior but not terminal; anterior end smoothly rounded into the ventral margin; posterior end also smoothly rounded, with no marked posterior truncation; posterior umbonal angulation low and broad, extending from the umbo to the ventral posterior margin; sculpture consisting of narrow concentric lamellae paralleling the border of the shell, and of strong undulations developed upon the dorsal posterior border, paralleling the growth lines dorsally but dying out along the posterior umbonal angulation; undulations variable in their development on different individuals; internal characters of the shell unknown.

EXPLANATION OF PLATE 45

All figures are natural size except as otherwise stated. The letters CIT are an abbreviation of California Institute of Technology.

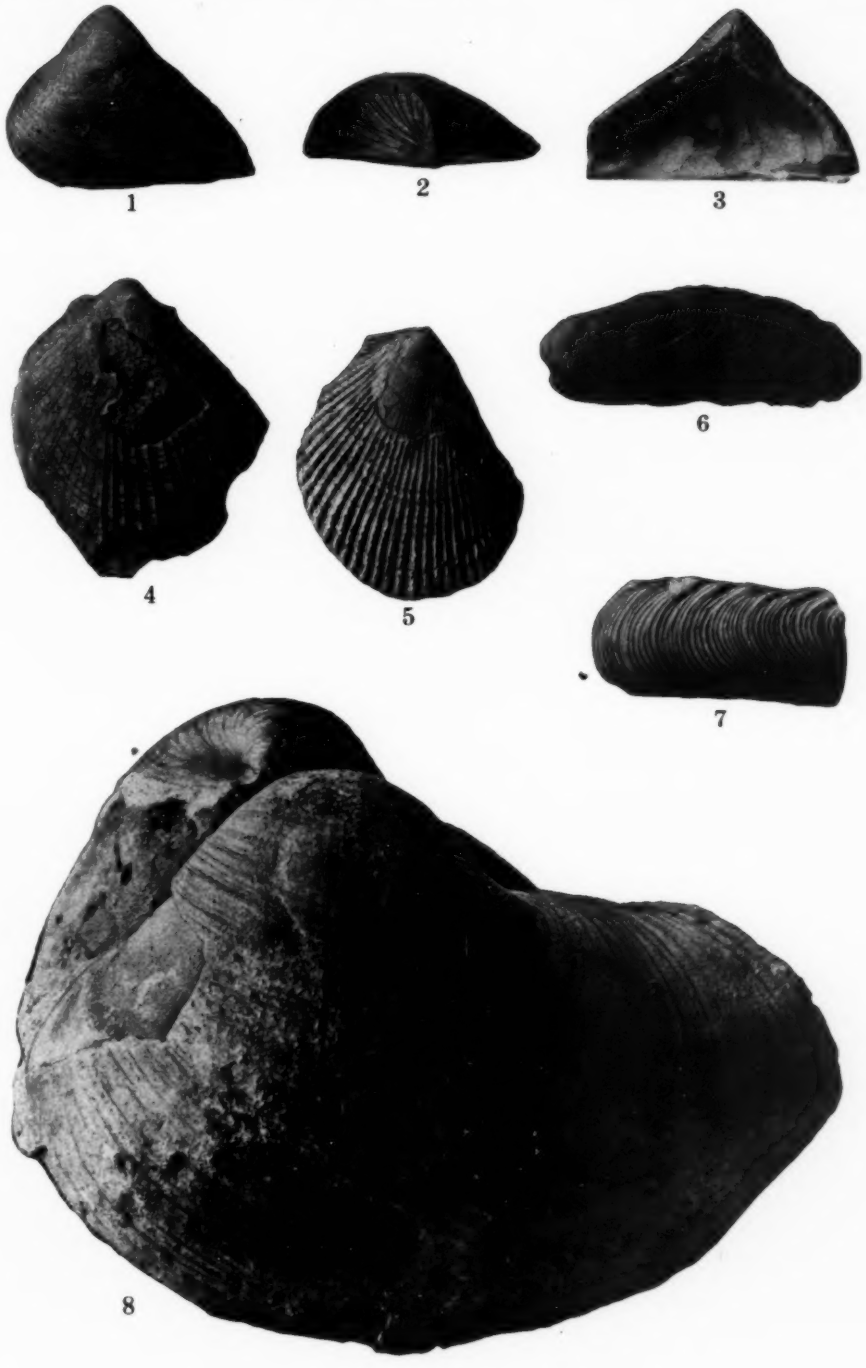
FIGS. *1–3—Trinacria cor* Popenoe, n. sp. Holotype, CIT Cat. no. 3418. ×2. *1,* Exterior of left valve; *2,* umbonal view of left valve; *3,* hinge of left valve. (p. 380)

4—Lima (Limatula) sp. cf. *L. suciensis* Whiteaves. Figured example, CIT Cat. no. 3422. ×2. Exterior of right valve. (p. 381)

5—Lima (Acesta) beta Popenoe, n. sp. Holotype, CIT Cat. no. 3424. Exterior of right valve. (p. 382)

6, 7—Inoperna bellarugosa Popenoe, n. sp. *6,* Holotype, CIT Cat. no. 3420. Exterior of left valve; *7,* Paratype, CIT Cat. no. 3421. Fragment of right valve showing characteristic coarse undulations on dorsal posterior border. (p. 382)

8—Liopistha (Psilomya) hardingensis (Packard). Figured specimen. CIT Cat. no. 3426. View of complete individual from left side. (p. 383)



Popenoe, Upper Cretaceous Mollusca

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Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3420; paratype, no. 3421.

Dimensions of holotype: Length, 42.3 mm., height, 18.7 mm., thickness of both valves, 13.9 mm.

Distribution: Ladd formation, Baker member, *common*.

Discussion: *Inoperna bellarugosa* resembles *Volsella siskiyouensis* (Gabb) somewhat in the character of the sculpture, but differs from the latter species by the characteristic dorsal posterior undulatory sculpture of *Inoperna*, by its more smoothly rounded posterior margins, and by the more gently tapering outline of the shell. *Inoperna bellarugosa* probably represents those forms from the Santa Ana Mountains that have been identified as *V. siskiyouensis*.

Inoperna flagellifera (Forbes) from the Valudayur group of India (Stoliczka, 19, p. 379) and the upper Greensand of England (Woods, 21, vol. 1, p. 99) is longer and more slender than *I. bellarugosa*. *I. carolinensis* Conrad, the genotype, from the Upper Cretaceous of the Atlantic and Gulf Coast of the United States, apparently has the dorsal undulations somewhat more numerous and less pronounced. Woods (21, p. 99) states that "*Modiola*" *flagellifera* belongs to a molluscan group characteristically developed in the Jurassic rocks.

Genus BRACHIDONTES Swainson

Genotype: *Brachidontes sulcata* Swainson.

BRACHIDONTES BIFURCATUS Popenoe, n. sp.

Plate 46, figure 2

Description: Shell small, thin, inflated; beaks low, incurved, markedly anterior; anterior end narrow, inflated, rounded; dorsal margin straight, two-thirds the length of the entire shell; posterior margin gently convex, obliquely truncate; ventral margin slightly emarginate; posterior umbonal ridge sharply angular near the beaks, becoming progressively lower and more broadly rounded toward the posteroventral border; sculpture consisting of numerous close-set radiating flat-topped ribs, separated by interspaces as wide as the ribs, strongly developed on the posterodorsal slope of the shell and on the umbonal ridge, where they bifurcate in some individuals; radial sculpture abruptly disappears slightly in advance of the umbonal angulation; sculpture on the anterior portion of the shell usually of growth lines only, or with very minute radial striae in addition; internal shell border crenate; dentition unknown.

Holotype: California Inst. Technology Invert. Paleo. Cat. no. 3425.

Dimensions of holotype: Length, 8.0 mm., height, 5.0 mm., thickness of one valve, 2.0 mm.

Distribution: Williams formation, *very rare*.

Discussion: This species is placed in the genus *Brachidontes* on the basis of the shape and sculpture of the shell, and of the crenate inner margin, which is visible in broken specimens. This appears to be the first record of *Brachidontes* in the Cretaceous of the Pacific Coast. The genus has been recognized in the Upper Cretaceous beds of the Western Interior region of the United States and Canada by Meek, White, Stanton, and others, and by Woods (21, vol. 1, p. 101 et seq.) in the Greensand of England.

Family POROMYACIDAE

Genus LIOPISTHA Meek

Section PSILOMYA Meek

LIOPISTHA (PSILOMYA) HARDINGENSIS (Packard)

Plate 45, figure 8; plate 46, figure 16

Homomya hardingensis PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 423, pl. 32, figs. 1a, 1b.

Description: These notes supplement the original description of the species. Sculpture consists of rather coarse concentric growth lines, of undulatory concentric ridges strongly developed in the region of the beaks but becoming progressively fainter ventrally and vanishing

at a distance of three or four centimeters ventral to the beaks, and of radial lines strongly developed at the beaks but appearing on the ventral flanks of the shell as rows of rather widely spaced raised granules. Where these granules have been broken off, their bases appear as shallow pits. Dentition not well shown but consists apparently of two lamellar teeth in the right valve, the anterior tooth being smaller and oblique; one rather small tooth in the left valve separates the sockets that receive the right cardinals; ligament external and rather short; a pronounced ridge extends from the beak to the anterior extremity delimiting a concave anterior dorsal area devoid of sculpture except for growth lines; anterior end apparently close; posterior end narrowly gaping.

Distribution: Ladd formation, Baker member, *rare*.

Discussion: This large shell is a *Liopistha* of the group of *L. superba* (Stoliczka) from the Trichinopoly group of India, and of *L. gigantea* (Sowerby) from the Upper Cretaceous beds of Blackdown, England. *L. hardingensis* differs from both of these other species in having a narrower and more pointed posterior end. I have found no reference to the presence of members of the section *Psilomya* elsewhere in the Cretaceous of North America.

Section LIOPISTHA s.s.

LIOPISTHA ANAANA (Anderson)

Plate 46, figures, 1, 3

Pholadomya anaana ANDERSON, *1902*, Calif. Acad. Sci., Proc., (3), vol. 2, no. 1, p. 73, pl. 7, fig. 151.

Liopistha anaana PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 146.

Description: These notes may be added to the original description: Hinge of the left valve with two cardinal teeth, posterior tooth rather oblique and strong; anterior left cardinal parallel to the hinge margin, smaller than the posterior cardinal; hinge of the right valve also with two cardinal teeth; posterior cardinal blunt, oblique, situated close up under the anterior hinge margin, bounded above and below by sockets that receive the cardinal teeth of the left valve; right anterior cardinal very small, broken; ligament external, narrow, short; posterior dorsal slope unornamented except for growth lines; strong radial ribs are found immediately before the posterior dorsal slope, continuing to the anterior region of the shell where they become progressively finer and more close-set; valves apparently close in front, gaping behind.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic*.

Discussion: *Liopistha anaana* is probably to be referred to *Liopistha* s.s. as

EXPLANATION OF PLATE 46

FIGS. *1, 3—Liopistha anaana* (Anderson). ×1½. Figured examples, CIT Cat. no. 3427. *1*, Hinge of right valve; *3*, Hinge of left valve. (p. 384)

2—Brachidontes bifurcatus Popenoe, n. sp. Holotype, CIT Cat. no. 3425. ×3. Exterior view of right valve. (p. 383)

4—Etea angulata (Packard). Figured example, CIT Cat. no. 3461. ×2. Hinge of right valve of immature specimen. (p. 385)

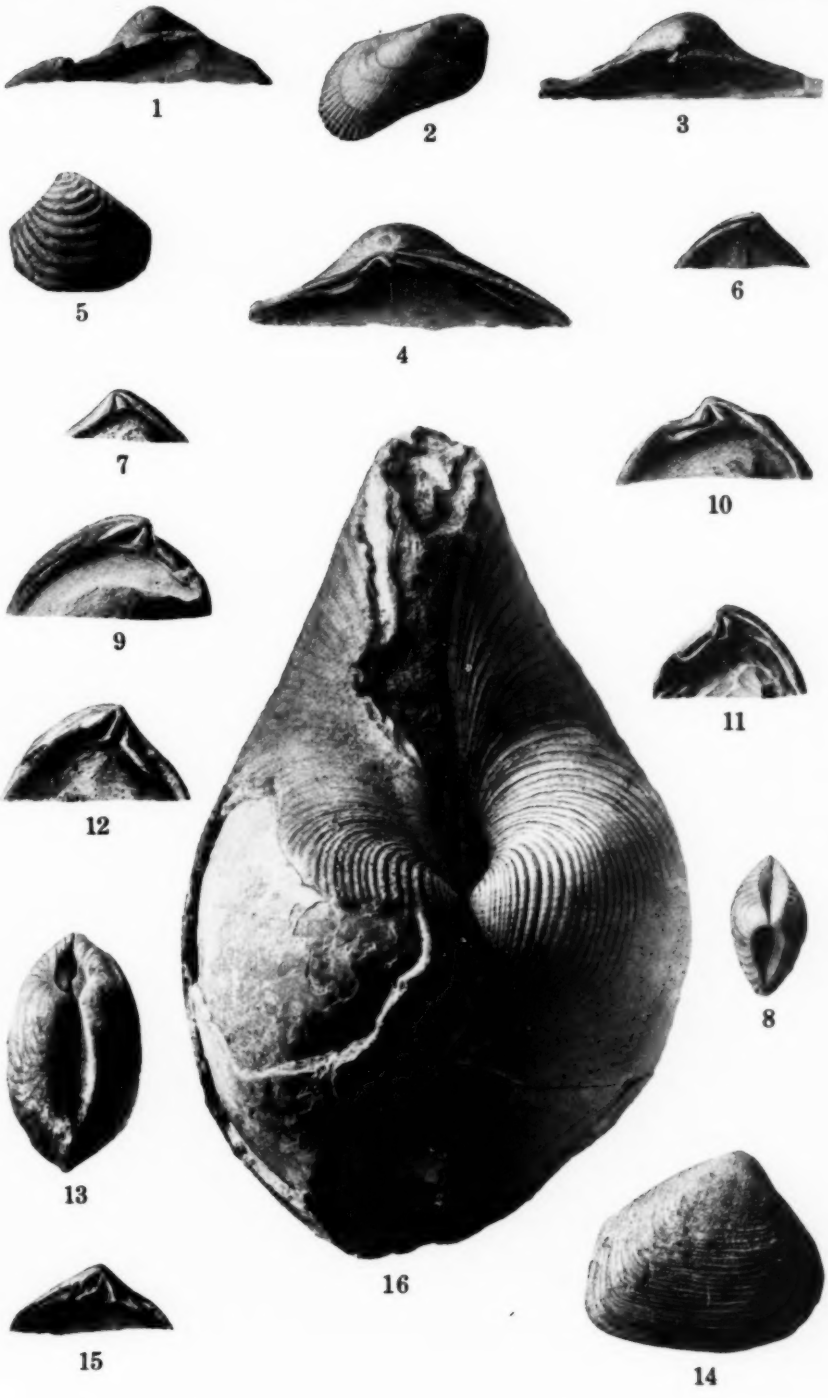
5–8—Astarte sulcata Packard. Figured examples, CIT Cat. no. 3428. ×2. *5*, Exterior of left valve; *6*, hinge of left valve; *7*, hinge of right valve; *8*, umbonal view of complete specimen. (p. 386)

9, 10—Eriphyla ovoides (Packard). Figured examples, CIT Cat. no. 3429. *9*, Hinge of left valve; *10*, hinge of right valve. (p. 386)

11, 12—Eriphyla lapidis (Packard). Figured examples, CIT. Cat. nos. 3430, 3431. *11*, Hinge of right valve; *12*, hinge of left valve. (p. 387)

13–15—Crassatella gamma Popenoe, n. sp. Holotype, CIT Cat. no. 3433. *13*, Umbonal view of complete specimen; *14*, exterior view of right valve. *15*, Paratype, CIT Cat. no. 3434. Hinge of left valve. (p. 388)

16—Liopistha (*Psilomya*) *hardingensis* (Packard). Figured example, CIT Cat. no. 3426. Umbonal view of complete specimen, showing concentric sculpture around the beaks. (p. 383)



Popenoe, Upper Cretaceous Mollusca

UNIV. OF MICH.

defined by Meek. Certainly the radial sculpture is the more prominent element in the ornamentation of the shell. There is a suggestion of concentric undulatory sculpture in the umbonal regions of well-preserved specimens, but this is seldom discernible far down on the sides of the valves. The radial sculpture is more prominent on the posterior part of the valves, but in some individuals as many as twelve to fifteen radial ribs growing weaker anteriorly are visible.

Dr. L. W. Stephenson, of the United States Geological Survey, informs me (oral communication) that the specimens of *Liopistha* s.s. that he has studied from the Atlantic Coast and Western Interior Cretaceous localities all show fine denticulations on the radial ribs. I have not seen any such ornamentation on any of the specimens from the Santa Ana Mountains. Its absence may be due to preservation, but I am inclined to believe these denticulations were never present on the California specimens. On the other hand, a few well-preserved individuals from the Santa Ana Mountains show what appear to be radial rows of broken-off tubercles suggestive of the sculpture of the section *Psilomya* as mentioned in the discussion of *L. hardingensis* above.

Pholadomya lucerna (Forbes) of the Trichinopoly and lower Valudayur beds of southern India strongly resembles *Liopistha anaana* in external aspect and if Meek (13, p. 235) is correct in assuming the Indian species to be a *Liopistha* the two forms are undoubtedly very closely allied. The chief external difference appears to be that the radial sculpture of *Pholadomya lucerna* is more strongly developed on the anterior areas of the shell.

Order TELEODESMACEA
Family PLEUROPHORIDAE

Genus ETEA Conrad

Genotype: *Etea carolinensis* Conrad.

ETEA ANGULATA (Packard)

Plate 46, figure 4.

Meretrix angulata PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 425, pl. 33, fig. 5.

Description: The following notes supplement the original description of this species: Dentition of the right valve consists of two cardinal teeth and two lateral sockets; right anterior cardinal thin, laminar, oblique, lying close up under the lunular border; right posterior cardinal longer, more robust, weakly bifid, the anterior element of the bifid tooth being short and splintlike; tooth obliquely ventrally directed; anterior socket deep, short, close to the anterior cardinal; posterior socket deep, narrow, long, situated midway between the umbo and the posterior end of the shell; dentition of the left valve consists of two cardinal teeth and two lateral teeth; anterior cardinal stout, triangular, weakly bifid, situated directly beneath the beak; posterior cardinal long, thin, laminar, close up under the nymph; anterior lateral close to the beaks, short, stout, prominent; posterior lateral long, thin, distant from the beaks; ligament rather short, narrow, external; pallial line simple.

Distribution: Ladd formation, Holz shale member, *abundant* and *characteristic*.

Discussion: *Etea angulata* is characteristic of a zone in the Holz shale comprising several hundred feet of beds near the middle of the section. At this horizon the species is abundant and widespread. It has also appeared rarely in beds both near the top and near the bottom of the shale member.

Etea was erected by Conrad as a subgenus of *Veniella*. It has usually been so considered, but Stephenson (16, p. 392), in a recent publication has accorded *Etea* generic rank. This procedure is followed here. In comparison with *Veniella*, as typified by *V. mortoni* Conrad, *Etea* has a much thinner shell and more delicate hinge, is generally smooth instead of having a sculpture of coarse concentric corrugations and costae, has the posterior lateral teeth farther removed from the beaks, and apparently lacks the trans-

verse striations of the posterior laterals.

Etea has not been reported elsewhere on the Pacific Coast and I have found no reference to it elsewhere in the literature on the Upper Cretaceous of the Indo-Pacific region. The genus is represented in a number of localities in the Upper Cretaceous of the Atlantic and Gulf Coastal Plain of the United States. None of the specimens I have seen from these regions are so robust as *E. angulata*.

Family ASTARTIDAE

Genus ASTARTE Sowerby

ASTARTE SULCATA Packard

Plate 46, figures 5–8

Astarte? sulcata PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 424, pl. 33, fig. 6.

Description: The following notes are added to the original description of this species: Lunule and escutcheon both well-marked, rather broad, long, unsculptured; ligament short, small, inserted in a narrow trough; dentition of the right valve, one strong trigonal posterior tooth immediately beneath the beaks, and one very small laminar anterior tooth directed obliquely toward the ventral anterior border and situated close up under the lunule; dentition of the left value, one strong central trigonal cardinal; dorsal anterior margin of right valve and dorsal posterior margin of left valve fit into long, narrow and shallow grooves on the corresponding margins of the opposite valves; pallial line simple; internal margins of the valves smooth.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic*.

Discussion: The genus *Astarte* s. l., has been divided into many sections and subgenera of which the distinctions are both confused and confusing. The subdivision of the genus to which *A. sulcata* is to be referred is yet uncertain. The species agrees fairly well with a species figured and discussed by Meek (13, p. 124) as *Eriphyla gregaria* M. and H. Meek, however, questions the reference of this latter species to *Eriphyla*, and it seems impossible that it should belong to this genus. *A. sulcata* appears to agree well with the *Astarte subcostata* group as figured and discussed by Woods (21, vol. II, p. 109 et seq.). Small astartes of this general type appear to be rather common in the Upper Cretaceous of Europe. With the possible exception of "*Eriphyla*" *gregaria* mentioned above, I know of no very closely related species in the American Interior or East Coast Cretaceous beds.

Genus ERIPHYLA Gabb

ERIPHYLA OVOIDES (Packard)

Plate 46, figures 9, 10

Astarte ovoides PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 424, pl. 30, fig. 1.

Description: The following notes may be added to the original description: Dentition consists of two cardinal teeth in each valve, and of a posterior lateral tooth in the right valve and a corresponding posterior lateral socket in the left valve; right posterior cardinal heavy,

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EXPLANATION OF PLATE 47

FIGS. *1*—*Crassatella gamma* Popenoe, n. sp. Paratype, CIT Invert. Paleo. Cat. no. 3434. Hinge of right valve. (p. 388)

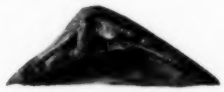
2, 3—*Crassatella lomana* Cooper. Figured examples, CIT Cat. no. 3432. *2*, Hinge of left valve; *3*, hinge of right valve. (p. 387)

4–6—*Pachycardium coronaense* (Packard). Figured examples, CIT Cat. no. 3435. *4*, Exterior of left valve; *5*, hinge of right valve; *6*, hinge of left valve. (p. 388)

7, 8, 11—*Isocardia delta* Popenoe, n. sp. Holotype, CIT Cat. no. 3436. *7*, Anterior view; *8*, exterior of left valve. *11*, Paratype, CIT Cat. no. 3438. Hinge of left valve. (p. 389)

9, 10, 12—*Clisocolus corrugatus* Popenoe, n. sp. Holotype, CIT Cat. no. 3439. *9*, Umbonal view of left valve; *10*, exterior view of valve; *12*, hinge of left valve. (p. 390)

13—*Cyprimeria moorei* Popenoe, n. sp. Syntype, CIT Cat. no. 3440. ×2. Hinge of right valve. (p. 391)



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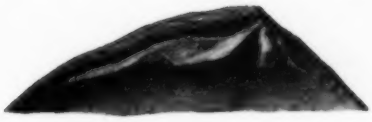

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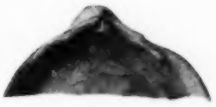

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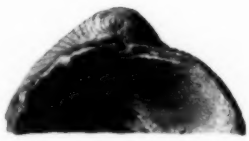

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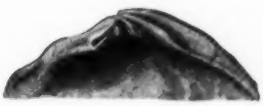


13

Popenoe, Upper Cretaceous Mollusca

UNIV. OF MICH.

oblique, trigonal; right anterior cardinal narrow, thin, situated vertically beneath the beak; right posterior lateral long, straight, rather heavy; left anterior cardinal rather heavy, situated nearly vertically beneath the beak; left posterior cardinal long, thin, curved, set close up under the nymph; posterior lateral socket long, narrow, shallow; ligament external, rather long; lunule short, deeply impressed; edge of left lunular margin projecting, and fitting into a narrow elongate socket just below the lunule of the right valve.

Distribution: Ladd formation, Baker member, *rare;* ?Holz shale member, *rare.*

Discussion: *Eriphyla* has been regarded as a subgenus of *Astarte* by many writers and as a genus of the Astartidae by as many others. Dall (8) considered *Eriphyla* more nearly related to the Crassatellidae. Stoliczka (19, p. 156) referred the genus to the Veneridae, near *Dosinia*. Meek (13, p. 122) questioned the generic position of the forms referred to *Eriphyla* by Stoliczka largely on account of the presence in Stoliczka's species of a slightly sinuous pallial line. Meek admitted that he had not seen the pallial line of the type of *Eriphyla* and admitted also that Stoliczka's species otherwise agreed well with Gabb's definition of the genus. Since that time, Woods (21, vol. 2, pls. 16, 17) has figured specimens of *Eriphyla* showing a sinuous pallial line, as has also Holzapfel (11, pl. 14). Specimens of *Eriphyla*, probably representing *E. umbonata* Gabb, now in the California Institute of Technology collections from the Upper Cretaceous beds at Clover Creek, Shasta County, California, also show this gently sinuous pallial line plainly. This feature alone is probably sufficient to separate *Eriphyla* generically from *Astarte*. *Eriphyla* is here regarded as a separate genus, tentatively placed in the Astartidae.

ERIPHYLA LAPIDIS (Packard)
Plate 46, figures 11, 12

Astarte lapidis PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 423, pl. 30, figs. 4a, 4b.

Distribution: Ladd formation, Holz shale member, *common.*

Discussion: Hinges of both valves of this species have been revealed and agree fully with Gabb's diagnosis of *Eriphyla*. They also agree fully with the dentition of *Eriphyla ovoides* (supra) and with hinges of specimens from Clover Creek, Shasta County, believed to represent *E. umbonata* Gabb.

Eriphyla lapidis bears considerable resemblance to *E. umbonata* in its general form and sculpture. Better material than that now available may show the two to be conspecific. *E. lapidis* seems to average larger than does *E. umbonata*, and seems likewise to be somewhat more ovoid in outline, however.

Family CRASSATELLIDAE

Genus CRASSATELLA Lamarck
Subgenus PACHYTHAERUS Conrad

CRASSATELLA LOMANA Cooper
Plate 47, figures 2, 3

Crassatella lomana COOPER, *1894*, Calif. State Min. Bur., Bull. 4, p. 48, pl. 3, fig. 47.—PACKARD, *1916*, Univ. Calif., Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 146.

Distribution: Ladd formation, Holz shale member, *very abundant* and *characteristic;* ?Williams formation, *very rare.*

Discussion: This massive *Crassatella* is at once one of the most abundant, most characteristic, and most widely distributed fossils from the upper part of the Holz shale. It is present in great numbers in nearly every fossil collection from this part of the section, and occurs at but few other horizons.

Crassatella lomana was originally described from the Cretaceous shales at Point Loma Peninsula, San Diego. Cooper, in his original description, stated that the fossil lacked the concentric ridges of *C. tuscana*, being sculptured only by coarse lines of growth. In well-preserved specimens these growth-lines show considerable regularity and differ from the more finely chiseled ornamentation of *C. tuscana* more in degree than in kind. The only specimens of *C. tuscana*

now available to me are from Sucia Island, in the Gulf of Georgia. These specimens are somewhat smaller than *C. lomana*, have finer sculpture, rather more inflated shape, shorter posterior end, and a broader dorsal slope. The two species are probably closely related, but are undoubtedly distinct.

CRASSATELLA GAMMA Popenoe, n. sp.

Plate 46, figures 13–15; plate 47, figure 1

Description: Shell of moderate size, rather high, short, compressed, angular in outline; beaks not very prominent, slightly anterior to the middle of the shell, prosogyrate; lunule depressed, long, narrow, about two-thirds the length of the anterior dorsal border; anterior dorsal border nearly straight; anterior portion of ventral border rounded; posterior half of ventral border nearly straight; posterior end abruptly truncate nearly at right angles to the ventral posterior border; posterior dorsal slope comparatively broad, plane, bounded below by an abrupt umbonal angulation; escutcheon long, narrow; sculpture of fine concentric close-set rather irregular ridges.

Dentition of right valve: one strong trigonal posterior cardinal tooth directly beneath the beak bounded anteriorly by a narrow oblique socket and posteriorly by a rather deep triangular socket; anterior cardinal tooth nearly obsolete; ligament pit a triangular depression in the dorsal half of the hinge plate immediately behind the posterior cardinal tooth; anterior dorsal border bears a shallow lateral socket situated below the forward part of the lunule; posterior lateral tooth long, narrow, straight. Dentition of the left valve: anterior cardinal tooth narrow and oblique; posterior cardinal tooth rather short and thick, bounded above by the chondrophore; anterior lateral tooth short and narrow, situated below the anterior end of the lunule; posterior lateral socket long, narrow, extending nearly the full length of the escutcheon.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3433.

Paratypes: California Inst. Technology, Invert. Paleo. Cat. no. 3434.

Dimensions of the holotype: Height, 26.0 mm., length, 30.5 mm., thickness of both valves, 17.1 mm.

Distribution: Ladd formation, Baker member, *abundant;* Holz shale member, *rare.*

Discussion: This *Crassatella* is common in and characteristic of the basal part of the Holz shale and of the uppermost part of the Baker member. It appears to have a limited stratigraphic range. It is somewhat similar to *Crassatella tuscana* in appearance, but differs from that form in being relatively higher, more compressed laterally, more sharply truncate posteriorly, with straighter ventral and dorsal margins, a longer and narrower lunule, and in general, greater angularity of form. I do not know of the appearance of this species outside of the Santa Ana Mountains region.

Superfamily CARDIACEA
Family CARDIIDAE

Genus PACHYCARDIUM Conrad

Genotype: *Cardium spillmani* Conrad.

PACHYCARDIUM CORONAENSE (Packard)

Plate 47, figures 4–6

Cardium coronaensis PACKARD, *1922*, Univ. Calif., Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 424, pl. 30, fig. 2.

Description: Shell small to medium in size, moderately inflated, shell substance rather thick; beaks high, narrow, prominent, prosogyrous, approximate; anterior dorsal margin broadly rounded, merging with a smooth curve into the arcuate ventral margin; posterior margin nearly vertically truncate, meeting the posterior ventral margin with an angle of slightly less than 90°; posterior dorsal border very short; ligament short and depressed; lunule restricted by a delicate incised line; hinge plate heavy; hinge angle approximately 55°.

Sculpture of the anterior and central slopes of the shell consists of delicate

incised evenly and closely spaced concentric lines that are most evident on the umbonal region and become progressively fainter ventrally; concentric sculpture usually nearly or quite invisible on the ventral regions of well preserved shells but generally well-shown on eroded specimens; sculpture of the posterior slope consists of about twenty very low delicate close-set rounded radial ribs that are most strongly developed next to the sharp humeral angle of the shell and become progressively fainter posteriorly; shell margin faintly denticulate where these ribs terminate.

Dentition consists of two cardinal teeth in each valve and strong anterior and posterior laterals; right anterior cardinal small, weak, anteriorly directed; right posterior cardinal strong, peglike, situated directly beneath the umbo; left anterior cardinal short, strong; left posterior cardinal thin and weak, directed obliquely backward; lateral teeth of both valves strong, distant from the beaks.

Distribution: Ladd formation, basal beds of Holz shale member, *rare*.

Dimensions of an example: Length, 31.8 mm., height, 32.8 mm., thickness of one valve, 9.5 mm. Dimensions of a second example: Height, 27.5 mm., length, 26.3 mm., thickness of one valve, approximately 8.6 mm.

Discussion: This species is believed to be identical with the one described by Packard from the Santa Ana Mountains as *Cardium coronaensis*. The sculpture of the type specimen of "*Cardium*" *coronaensis* has been destroyed by weathering, but in general shape, outline, and size, as well as in stratigraphic position the material used in my own study agrees well with Packard's type specimen.

Stewart (18, p. 277) has discussed the generic characters and distribution of *Pachycardium* and suggests that the genus is the Upper Cretaceous descendant of the Lower Cretaceous *Protocardia*. *Pachycardium* apparently is limited in its distribution to beds of Upper Cretaceous age. The genotype is from the Ripleyan of Owl Creek, Mississippi. Stewart mentions also the presence of *Pachycardium* in deposits at Coon Creek, Tennessee (*P. stantoni* (Wade)), and in the Ootatoor group of India (*P. bisectum* (Stoliczka)). Dr. A. Myra Keen, of Stanford University (personal communication), has noted the presence of the genus, in addition, in the Upper Cretaceous beds of New Jersey and Syria. She suggests that *P. coronaense* represents the first recorded appearance of the genus in the Upper Cretaceous of the Pacific Coast.

Superfamily ISOCARDIACEA
Family ISOCARDIIDAE

Genus ISOCARDIA Lamarck
Genotype: *Isocardia cor* Lamarck.

ISOCARDIA DELTA Popenoe, n. sp.
Plate 47, figures 7, 8, 11

Description: Shell of medium size, thin, fragile, greatly inflated; beaks very high, prominent, distant, spirally coiled, prosogyrous; anterior dorsal margin deeply concave below the beaks; anterior extremity obtuse and rounded; ventral margin broadly curved; posterior extremity meeting the ventral margin at an abrupt angle and merging with the dorsal posterior border in a sweeping curve; dorsal posterior slope and lateral face of the shell meeting along a rounded curving angulation extending from the beaks to the ventral posterior border; ligament narrow, rather short, external; lunule and escutcheon undefined; pallial line unknown.

Dentition of the right valve consists of two curved laminar teeth arranged parallel to the hinge-line, situated one above the other, separated by a groove that receives the ventral cardinal tooth of the left valve; left valve also with two laminar horizontal cardinal teeth, the posterior and dorsal tooth extending from the hinge-line posteroventrally; anterior and ventral cardinal parallel to the hinge border below the beaks, separated from the hinge border by a narrow groove, excavated on the ventral surface; lateral teeth apparently absent.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3436.

Paratypes: California Inst. Technology Invert. Paleo. Cat. nos. 3437, 3438.

Dimensions of holotype: Height, 39.6 mm., length, 34.0 mm., thickness of both valves, 34.6 mm.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic.*

Discussion: *Isocardia delta* is found in a narrow zone essentially including the uppermost beds of the Baker member. The shell of this species is very fragile, and few of the specimens collected have escaped crushing and distortion. *Isocardia delta* is probably at least subgenerically distinct from *I. cor*, the genotype, for the Cretaceous species lacks the characteristic posterior lateral teeth that are present in *I. cor* and in every other Tertiary or Recent *Isocardia* that I have seen. *Isocardia delta* was recognized in the Santa Ana Mountains Upper Cretaceous fauna by Packard but was not described.

A few other species of *Isocardia* have been described from Upper Cretaceous deposits both in the Atlantic Coastal Plain region and in Europe. The genus seems rare in the Cretaceous, however. *I. delta* seems to be the first definite record of the genus in the Pacific Coast Cretaceous deposits, for *Isocardia chicoensis* Waring appears to be a *Clisocolus*, probably *C. cordatus* Whiteaves.

Genus Clisocolus Gabb

Clisocolus corrugatus Popenoe, n. sp.
Plate 47, figures 9, 10, 12

Description: Shell of medium size, highly inflated, gibbous in outline; shell substance rather thick; beaks high, prominent, prosogyrous, sharply incurved; outline of shell margin below the beaks nearly circular to slightly oval; lunule and escutcheon undefined; ligament external, lodged in a deep narrow furrow; hinge edentulous but with a slight thickening of the hinge-line below the beaks and with a shallow pit centrally placed, dorsal to the thickened part; lateral teeth absent; sculpture consisting of rather coarse raised concentric corrugations, spaced at approximately 2 mm. intervals on the median flanks of the mature shell; character of muscle scars and pallial line unknown.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3439.

Dimensions of holotype: Height, 31.5 mm., length, 31.5 mm., thickness of one valve, 14.4 mm.

Distribution: Ladd formation, Baker member, *rare.*

Discussion: *Clisocolus corrugatus* is readily distinguished from *C. cordatus* Whiteaves by the character of its coarse widely spaced concentric sculpture. Usually the latter species is larger, higher, and more gibbous in outline than *C.*

Explanation of Plate 48

Figs. *1, 2—Cyprimeria moorei* Popenoe, n. sp. Syntypes, CIT Cat. no. 3440. ×2. *1*, Exterior of right valve; *2*, hinge of left valve. (p. 391)

3, 5—Tenea inflata (Gabb). Figured examples, CIT Cat. nos. 3441, 3442. *3*, Hinge of right valve; *5*, hinge of left valve. (p. 391)

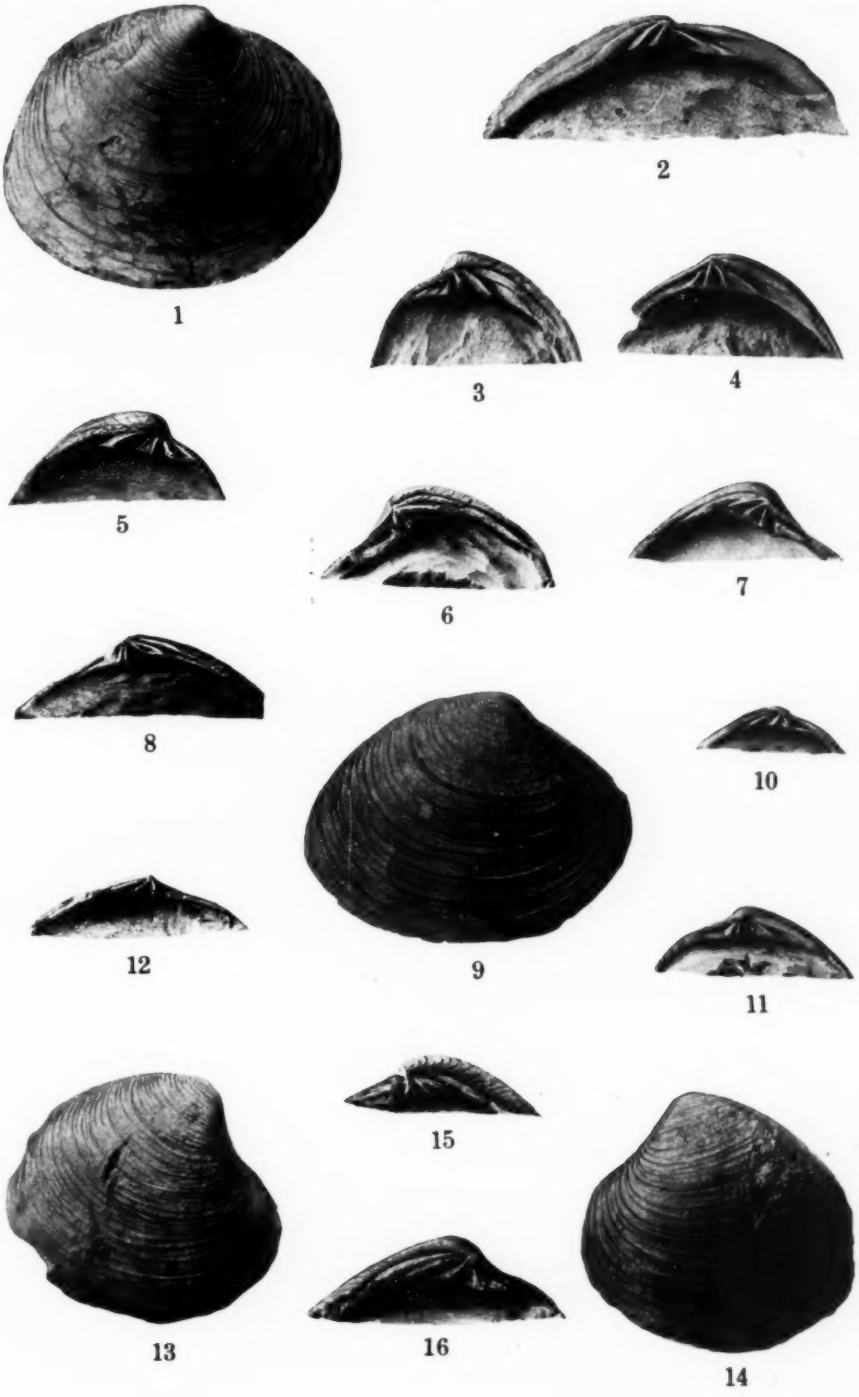
4—Flaventia lens (Gabb). Figured example, CIT Cat. no. 3443. Hinge of right valve of a specimen from Butte Creek, Butte County, California. (p. 392)

6, 7, 13, 14—Calva regina Popenoe, n. sp. and gen. Syntypes, CIT Cat. no. 3447. *6*, Hinge of right valve; *7*, hinge of left valve; *13*, exterior of right valve; *14*, exterior of left valve. (p. 395)

8, 12—Legumen oöides (Gabb). Figured examples, CIT Cat. no. 3446. *8*, Hinge of right valve; *12*, hinge of left valve. (p. 394)

9, 10, 11—Flaventia zeta Popenoe, n. sp. Holotype, CIT Cat. no. 3444. *9*, Exterior of right valve. Paratype, CIT Cat. no. 3445. *10*, Hinge of left valve; *11*, hinge of right valve. (p. 393)

15, 16—Aphrodina ? arata (Gabb). Figured examples, CIT Cat. nos. 3448, 3449. ×2. *15*, Hinge of right valve, *16*, hinge of left valve. (p. 397)



Popenoe, Upper Cretaceous Mollusca

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corrugatus. I do not know of the occurrence of this species outside of the Santa Ana Mountains.

Superfamily VENERACEA
Family VENERIDAE

Genus CYPRIMERIA Conrad

Genotype: *Cytherea excavata* Morton.

CYPRIMERIA MOOREI Popenoe, n. sp.
Plate 47, figure 13; plate 48, figures 1, 2

Description: Shell rather small, thin, fragile, compressed, oval in outline, slightly longer than high; beaks low, slightly anterior; margin very gently concave just in front of the beaks, elsewhere smoothly curved in a broad ellipse; ornamentation of fine regular growth-lines only; no lunule or escutcheon; ligament external, deep-seated, long, very narrow; pallial line with a shallow sinus.

Dentition of three cardinal teeth in each valve; anterior left cardinal long, very thin, thickening anteriorly, strongly oblique to the shell-margin above and the ventral hinge-plate margin below, bounded dorsally and ventrally by deep narrow sockets; median left cardinal short, broad, trigonal, situated directly below the beak; posterior left cardinal rather long, thin, slightly curved, diverging at an acute angle from the nymph which it underlies; anterior and median right cardinals thin and long, extending obliquely forward from the beaks, subparallel, but diverging somewhat anteriorly; posterior cardinal narrow, gently curved, extending obliquely posteroventrally from the beaks, thickening somewhat toward the posterior end, deeply cleft along the crest; lateral teeth absent.

Syntypes: California Inst. Technology, Invert. Paleo. Cat. no. 3440.

Dimensions of syntypes: Right valve, length, 27.3 mm., height, 21.6 mm., thickness of valve, approximately 4.2 mm.; left valve, length, 24.4 mm., height, 19.6 mm., thickness, approximately 2.3 mm.

Distribution: Ladd formation, Holz shale member, *rare*.

Discussion: This shell is named in honor of Dr. B. N. Moore, of the United States Geological Survey. Doctor Moore collected all of the material upon which this species is based, and generously made his collections available for this study.

Cyprimeria moorei is probably the first *Cyprimeria* to be reported from the Pacific Coast Upper Cretaceous. Whiteaves (20, p. 379) has referred to *Cyprimeria* several specimens from Sucia Island which he at first identified as *Meretrix lens* Gabb, a species since shown by Stewart to belong to the genus *Flaventia* Jukes-Brown (18, p. 247). It has been possible to expose the hinges of several specimens of *Flaventia lens* from the Santa Ana Mountains, from northern California, and from Sucia Island. The hinge characters of all of these agree almost exactly with those of *Flaventia ovalis* illustrated by Woods (21, vol. 2, p. 191, pl. 29, figs. 19–26), and with Whiteaves' illustration of the hinge of "*Cyprimeria*" *lens*. It is believed that Whiteaves' specimens are to be referred to *Flaventia* rather than to *Cyprimeria*. A second species cited by Whiteaves from the Upper Cretaceous of British Columbia, *Cyprimeria ? tenuis* Meek, is neither described nor figured, and its actual relationships are very dubious.

Genus TENEA Conrad

Genotype: *Tenea parilis* Conrad.

TENEA INFLATA (Gabb)
Plate 48, figures 3, 5

Dosinia inflata GABB, *1864*, Paleontology Calif., vol. 1, p. 168, pl. 23, fig. 149.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia Spec. Pub. 3, p. 231.

Description: The following notes are given on the dentition of this species: Right anterior cardinal very small, slender, short, diverging at a small angle from the hinge-margin directly anterior to the beak, extending ventrally only halfway across the hinge-plate; median right cardinal rather heavy, low, trigonal; posterior right cardinal heavy, long, slightly curved, situated close up under the nymph, from which it is separated

by a narrow groove; a thin lamellar ridge rising from the floor of the socket between the anterior and median right cardinals extends about halfway from the ventral edge of the hinge plate toward the beak; left anterior and median cardinals short, slender, joined dorsally, diverging ventrally at a high angle; posterior left cardinal long, laminar, oblique, situated just below the nymph; lateral teeth apparently absent; pallial sinus long, narrow, pointed, ascending, directed toward the umbos.

Distribution: *Dwarf variety*—Ladd formation, Baker member, *common; Giant variety*—Ladd formation, Holz member, *abundant.*

Discussion: *Tenea* has not been reported hitherto from the Pacific Coast Cretaceous, but is known from a number of localities in the Upper Cretaceous of the Atlantic and Gulf Coastal Plain of the eastern United States. The genotype is from the Cretaceous of New Jersey (Conrad, 3). *Cyclina magna* Wade from the Ripley formation of Coon Creek, Tennessee, is probably to be referred to this genus (personal communication from L. W. Stephenson) as may also be *Cyclina parva* Gardner of the Monmouth formation of Maryland. Holzapfel (11, p. 168, pl. 12, figs. 9–12) figures a shell identified as *Cytherea tumida* Goldfuss that is almost surely a *Tenea*. It is probable that many other Cretaceous species that have been described as *Dosinia* will be found referable to this genus.

A number of paleontologists have discussed the systematic position of *Tenea* without reaching any general agreement. Conrad originally suggested the relationship of *Tenea* to *Taras* [*Diplodonta*]. Many other writers, including Dall, Fischer, and Weller, have doubtfully or confidently placed this genus in the Ungulinidae. Whitfield on the other hand referred *Tenea* to the Veneridae, comparing it to *Dosinia*. It is my own opinion that *Tenea* is a Venerid genus, closely allied to *Dosinia* and *Cyclina*, though quite distinct from either. The reasons for this conclusion lie in the characters of the hinge, which appears to be typically Venerid in structure, and in the character of the long slender pointed ascending pallial sinus so similar to the sinuses of *Cyclina* and *Dosinia*.

Tenea inflata is represented by many excellent specimens from the middle and upper horizons of the Holz shale and from the uppermost beds of the Baker member. The specimens found in the shale are usually rather robust, thick-shelled, and large. Some of these individuals attain a height of 35 mm. Conversely, the specimens from the Baker member are invariably small, thin-shelled, and fragile. Few individuals from this part of the section will reach an altitude of as much as 20 mm. These differences are so constant and so closely correlated with stratigraphic position that one is tempted to consider that two species are represented. This view is strengthened by the fact that very few species are common to both the Baker sandstones and the Holz shale. Nevertheless, I have been unable to find any basis for separation of these forms other than size and thickness of shell, and feel these to be scarcely sufficient in themselves for separating species.

Genus FLAVENTIA Jukes-Brown

FLAVENTIA LENS (Gabb)

Plate 48, figure 4

Meretrix lens GABB, *1864*, Paleontology Calif., vol. 1, p. 164, pl. 23, fig. 143. *Cyprimeria lens* WHITEAVES, *1879*, Canada Geol. Survey, Mesozoic Fossils, vol. 1, pt. 2, p. 152, pl. 17, figs. 15, 15a; *ibid.* p. 379.

Flaventia ? lens STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 247, pl. 4, fig. 6.

Description: The following notes are offered on the hinge-structure of this species: Right anterior and median cardinals set close together, diverging ventrally, directed obliquely anteriorly; right posterior cardinals long, heavy, deeply bifid, the anterior element being short; left anterior and median cardinals short and strong, close together, diverging ventrally at a large angle; posterior

cardinal long, thin, situated below the nymph; ligament external, moderately long, submerged; lunule and escutcheon undefined; pallial sinus triangular, ascending; lateral teeth absent.

Distribution: Ladd formation, Holz member, *abundant;* Williams formation, *common.*

Discussion: Whiteaves (supra) was apparently the first to call attention to the hinge-structure of *Flaventia lens*, or at least was the first to publish his observations. He referred the species to *Cyprimeria*, but comparison of his figure of the hinge of a left valve with the hinge of true *Cyprimeria* reveals an error. Stewart (supra) first called attention to the similarity of the hinge of *F. lens* with that of *F. ovalis* (the genotype) and suggested the relationship, although he was unsuccessful in uncovering enough of the hinge of *F. lens* to permit him to feel sure of the identity. The present study verifies Stewart's determination of the generic position of *F. lens.*

FLAVENTIA ZETA Popenoe, n. sp.
Plate 48, figures 9–11

Description: Shell of medium size, strong, moderately inflated, elongate-oval in outline; beaks not very prominent, situated slightly anterior to the mid-length of the shell; anterior dorsal slope nearly straight from the beaks to the anterior end; ventral border smoothly curved between the anterior and posterior ends of the shell, forming nearly the arc of a circle; posterior dorsal border slightly arched, meeting the ventral border in a blunt angulation; ligament external, about one-half the length of the posterior dorsal border; lunule undefined; escutcheon spindle-shaped, long, narrow; ornamentation of growth-lines only, fine on the dorsal part of the shell, becoming coarse toward the ventral borders; pallial sinus short, broadly triangular, wide open at the base, ascending.

Hinge of three cardinal teeth and no laterals in each valve; right anterior and median cardinals short, slender, subparallel, diverging slightly distal to the beaks, directed obliquely forward from the beaks; right posterior cardinal strong, rather long, trigonal, very oblique, diverging at a small angle from the nymph, bifid, the anterior element being short and slender; left anterior and median cardinals short and thin, approximately equal in size, diverging from one another at a moderate angle directly ventral to the beaks; posterior left cardinal long, narrow, slightly curved, underlying and slightly divergent from the nymph; hinge plate of both valves shallowly excavated in front of the anterior teeth.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3444.

Paratypes: California Inst. Technology, Invert. Paleo. Cat. no. 3445.

Dimensions of holotype: Height, 33.2 mm., length, 44.7 mm., thickness of both valves, 18.0 mm.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic;* Holz shale member, *rare.*

Discussion: *Flaventia zeta* is to be distinguished from *F. lens* principally by its more elongate outline and by its higher beaks. Most of the mature specimens of *F. lens* are nearly equidimensional in length and height, whereas *F. zeta* is longer than high in the ratio of four to three. Assemblages of individuals of both species show considerable variation in shape, and end members of the variable series approach one another in proportions. Stratigraphically, the two species are complementary, *F. zeta* being common in the Baker member and very rare in the lower part of the Holz shale, whereas *F. lens* is common in the upper part of the Holz shale and rather rare in the Williams formation. The two species have not been found together.

Flaventia zeta appears to be represented in collections now at the California Institute of Technology from the basal Upper Cretaceous beds at Henley, Siskiyou County, California, and the species may be expected in other collections from northern California and southern Oregon from beds low in the Upper Cretaceous section. It may be repre-

sented in the fossil lists by forms that have been identified as *Flaventia lens*.

Genus LEGUMEN Conrad
Genotype: *Legumen ellipticum* Conrad.

LEGUMEN OOIDES (Gabb)
Plate 48, figures 8, 12

Tellina ooides GABB, *1864*, Paleontology Calif., vol. 1, p. 157, pl. 22, figs. 135, 135a.—ARNOLD, *1909*, U. S. Geol. Survey Bull. 396, p. 11, pl. 1, fig. 3.—PACKARD, *1916*, Univ. Calif., Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 147.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 202, pl. 3, fig. 3.

Description: These internal features of the shell have been determined for *Legumen ooides*—cardinal teeth, three in each valve; lateral teeth absent; right anterior and median cardinals short, slender, prominent, subparallel, situated almost directly beneath the beaks; right posterior cardinal long, moderately prominent, subparallel to the nymph, bifid, the anterior element of the tooth being short and splintlike; left anterior and median cardinals also short, slender, and prominent, diverging from one another ventrally at an angle of approximately sixty degrees; left posterior cardinal long and thin, joined to the ventral border of the nymph; hinge-plate shallowly excavated immediately in front of the anterior cardinal teeth; lunule undefined; ligament submarginal, about one-half the length of the posterior dorsal margin of the shell; pallial sinus rather short, broad, blunt, directed toward the anterior adductor scar.

Distribution: Williams formation, *rare*.

Discussion: The characters of the dentition, ligament, lunule, and pallial sinus of *Legumen* are very similar to those features in *Flaventia*. The principal differences separating these genera appear to be: (a) the species of *Flaventia* tend to have rather thick shells, either equal in length and height or not much longer than high; the species of *Legumen* are usually quite elongate and are thin-shelled. (b) The right posterior cardinal tooth of *Flaventia* is comparatively larger than the corresponding tooth in *Legumen*, is more deeply bifid, and the anterior element of the tooth is longer and thicker. These differences may prove to be of no more than subgeneric importance. *Flaventia* would then become a subgenus of *Legumen*.

Stephenson (15, p. 319) suggests that *Baroda* Stoliczka is probably generically identical with *Legumen*. If this be so, *Legumen* is represented by a number of species widely distributed in the Upper Cretaceous beds of the World. I have not seen the hinge of *Baroda*, and those illustrations of the hinge available do not show whether or not the right posterior cardinal tooth is bifid. Jukes-Brown (12, p. 171) describes this tooth in *Baroda* as "entire." Since the bifid right posterior cardinal appears to be a constant character in the American species of *Legumen*, *Baroda* is probably distinct.

Genus CALVA Popenoe, n. gen.
Genotype: *Calva regina* Popenoe, n. sp.

Generic diagnosis: Venerid pelecypods of medium to large size, with heavy shells characteristically ornamented by fine concentric growth-lines with occasional irregularly spaced deeper concentric grooves developed; shape usually moderately elongated, beaks prominent and high, lunule somewhat depressed, usually circumscribed by an incised line; hinge of each valve bearing three cardinal teeth; anterior and posterior lateral teeth present in the left valve; corresponding anterior and posterior lateral sockets developed in the right valve; left anterior lateral tooth parallel to the forward border of the nymph, smooth, rather long; left posterior lateral tooth formed by a slightly salient projection of the hinge border; right posterior lateral socket long, narrow, moderately deep, distant from the beaks; right posterior cardinal tooth weakly bifid.

Within this genus will fall all or nearly all of the forms formerly referred to "*Venus*" *varians* Gabb, "*Meretrix*" *nitida* Gabb, and the varieties listed in connection with these names; a number of Cretaceous species that have been de-

scribed under such generic names as *Callista, Cytherea, Meretrix, Venus;* and in addition, many, if not all, of the Cretaceous species hitherto referred to the genus *Dosiniopsis* Conrad.

Dosiniopsis was erected in 1864 by Conrad (2) with *Dosiniopsis meeki* from Eocene deposits near Washington, D.C., as the genotype. *D. meeki* was later declared to be simply a variant of *D. lenticularis* (Rogers) by Clark and Martin (6). Meek (13, p. 179) apparently was the first person to mention in print the presence of a posterior lateral tooth in this genus—a rare feature in a venerid shell. Cossman (4) recognized Conrad's genus and placed therein three species previously described by Deshayes from the Eocene of the Paris Basin—*D. fallax, D. bellovacensis,* and *D. orbicularis* (Edwards). Cossman does not mention the presence of a posterior lateral tooth in these forms, but in the illustrations of these species given in the "Iconographie Coquilles Fossiles de Paris" of Cossman and Pissarro, all views showing the interior of the right valve show the posterior lateral plainly. Of Cretaceous forms referred to *Dosiniopsis* may be mentioned *Cytherea caperata* Sowerby and *Cytherea subrotunda* Sowerby, placed in *Dosiniopsis* by Jukes-Brown (12, p. 151) and later figured and described by Woods (21, vol. 2, pp. 181, 182, pl. 28, figs. 1–10). Palmer (14) has referred *Meretrix unzambiensis* Woods of the Upper Cretaceous of Pondoland, South Africa, to *Dosiniopsis,* and Meek (13, p. 184) described *Dosiniopsis nebrascensis* from beds of the Fort Pierre and Fox Hills groups of the Dakota Upper Cretaceous.

A review of the descriptions and figures of the above species indicates that all of the Cretaceous species referred to *Dosiniopsis,* together with the Pacific Coast Cretaceous shells referred to *Venus varians, Meretrix nitida* and varieties, have posterior lateral teeth, anterior lateral teeth and sockets that are smooth and not striated, posterior cardinal teeth that are weakly bifid, and in general are elongate in form. All the Eocene shells placed in *Dosiniopsis,* including the genotype, have strong deeply bifid right posterior cardinal teeth, striated anterior lateral teeth and sockets, and in general, lenticular outline. These differences together with the age difference of the two groups appear to justify a new genus to accommodate the Cretaceous species.

To the genus *Calva* are tentatively assigned *Venus varians* Gabb, *Meretrix nitida* Gabb, *Meretrix nitida* var. *major* Packard, *Meretrix umzambiensis* Woods, *Cytherea subrotunda* Sowerby, *Cytherea caperata* Sowerby, *Dosiniopsis nebrascensis* Meek, *Callista pseudoplana* Yabe and Nagao, and "*Cucullaea*" *bowersiana* Cooper.

CALVA REGINA Popenoe, n. sp.
Plate 48, figures 6, 7, 13, 14

Description: Shell of moderate size, nearly as high as long, inflated, rather thick; beaks prominent, rather high, placed anterior to the mid-length of the shell, prosogyrous; anterior dorsal border strongly concave; anterior end rather sharply rounded; ventral border broadly arched; posterior end bluntly truncate vertically; posterior dorsal border rather short, slightly arched; posterior dorsal slope nearly flat, broad, marked off from the lateral portion of the shell by a low rounded ridge extending from the beak to the ventral posterior border; lunule heart-shaped, sunken, circumscribed by a fine line; escutcheon faintly marked off, extending the length of the posterior dorsal border; ornamentation of evenly spaced, moderately fine growth-lines only; ligament rather short, sunk below the shell margin; characters of the muscle scars and pallial line unknown.

Right anterior and median cardinal teeth short, narrow, prominent, close together, slightly divergent ventrally, situated directly beneath the beaks; right posterior cardinal long, straight, shallowly bifid, subparallel to the nymph; anterior lateral socket long, narrow, moderately deep, smooth, parallel to the lunular border of the shell; posterior right lateral socket deep, bounded below

by a rather large projecting tooth; left anterior cardinal prominent, very slender, aligned almost vertically beneath the beak; left median cardinal thicker than the anterior, trigonal, directed obliquely backward; left posterior cardinal continuous with the ventral side of the nymph, slightly longer than the anterior teeth, not very massive; anterior lateral teeth long, wedge-shaped, parallel to the hinge border below the lunule, smooth; posterior lateral tooth, a slightly salient portion of the shell-margin just posterior to the rear end of the nymph.

Syntypes: California Inst. Technology, Invert. Paleo. Cat. no. 3447.

Dimensions of syntypes: Right valve, height, 34.4 mm., length, 36.5 mm., thickness of one valve, approximately 8.5 mm.; left valve, height, 33.2 mm., length, 37.0 mm., thickness of valve, approximately 10.8 mm.

Distribution: Ladd formation, Baker member, *common* and *characteristic.*

Discussion: *Calva regina* is fairly widespread but not abundant in the Baker sandstones. It may be distinguished from *Calva bowersiana* (Cooper), found in the upper Holz shale member and the Williams formation, by its abruptly truncate posterior end and the rather high, short, posterior dorsal slope. *C. regina* averages considerably smaller than *C. bowersiana* also. *Calva nitida* of the northern California Upper Cretaceous appears to be more pointed posteriorly than *C. regina* and usually is sculptured with irregularly spaced rather deeply incised concentric grooves, marking resting stages of growth.

CALVA BOWERSIANA (Cooper)

Cucullaea bowersiana COOPER, *1894*, Calif. State Min. Bur., Bull. 4, pt. 5, p. 48, pl. 5, figs. 16, ?62.

Meretrix nitida GABB var. *major* PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 425, pl. 31, fig. 2.

Aphrodina major ANDERSON and HANNA, *1935*, Calif. Acad. Sci., Proc., (4) vol. 23, no. 1, p. 28.

Distribution: Holz shale member, Ladd formation *rare;* Pleasants member, Williams formation, *abundant* and *characteristic.*

Discussion: Dr. L. G. Hertlein, of the California Academy of Sciences, called my attention to the type specimen of "*Cucullaea*" *bowersiana* Cooper, which is in the type collections of the Academy. Apparently at the time Cooper described *C. bowersiana* the umbonal region of the type was concealed in the matrix. This has since been exposed by further preparation of the specimen, revealing the beaks, the ligament area, and the lunule. The type is a venerid shell specifically identical with the large form from the Santa Ana Mountains described by Packard as *Meretrix nitida* Gabb, var. *major.* Packard's variety is thus a syno-

EXPLANATION OF PLATE 49

FIGS. *1*—*Cymbophora ashburnerii* (Gabb). Figured example, CIT Cat. no. 3450. ×1½. Hinge of left valve. (p. 397)

2—*Cymbophora gabbiana* (Anderson). Figured example, CIT Cat. no. 3451. Hinge of right valve. (p. 398)

3—*Euspira shumardiana* (Gabb). Figured example, CIT Cat. no. 3452. Apertural view. (p. 398)

4, 5—*Ampullina packardi* Popenoe, n. sp. Holotype, CIT Cat. no. 3453. *4*, Apertural view; *5*, view of the body whorl. (p. 399)

6—*Turritella ossa* Popenoe, n. sp. Holotype, CIT Cat. no. 3458. ×1¾. Apertural view. (p. 401)

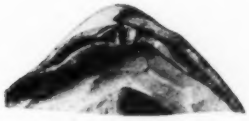
7—*Turritella chicoensis* Gabb. Figured example, CIT Cat. no. 3454. Typical dwarf variety. (p. 400)

8—*Turritella iota* Popenoe, n. sp. Holotype, CIT Cat. no. 3457. (p. 401)

9—*Turritella chicoensis* Gabb. Figured example, CIT Cat. no. 3455. Giant round-whorled variety. (p. 400)

10—*Turritella chicoensis* Gabb. Figured example, CIT Cat. no. 3456. Giant flat-whorled variety. (p. 400)

1



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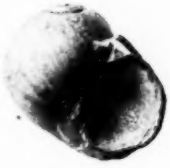

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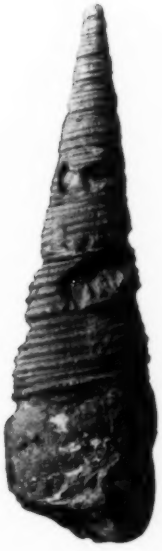

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10

Popenoe, Upper Cretaceous Mollusca

UNIV. OF MICH.

nym of "*C.*" *bowersiana* Cooper. Study of the hinge and other structural features of this large venerid shows it to accord well generically with the diagnosis of *Calva*, given above, and it is referred to that genus. *Calva bowersiana* is thought to be specifically distinct from *Calva nitida* (Gabb) and it is raised to the full rank of a species.

Identity of the specimen figured by Cooper with the specimen preserved in the California Academy of Sciences type collections is made certain by inspection of the cracks and fractures in the shell of the type specimen which have been perfectly reproduced in the figure (no. 61) given by Cooper to illustrate his new species *bowersiana*. As Cooper's specific name antedates Packard's by more than 30 years, it has unquestionable priority.

Calva bowersiana is found in the Upper Cretaceous beds of the Santa Monica Mountains and of the Simi Hills, southern California, and Anderson and Hanna (supra) have reported its presence in the Cretaceous of Santa Catarina Landing, Lower California.

Genus APHRODINA Conrad

APHRODINA? ARATA (Gabb)

Plate 48, figures 15, 16

Meretrix arata GABB, *1864*, Paleontology Calif., vol. 1, p. 166, pl. 30, fig. 250.—PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 146.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 247, pl. 1, fig. 4.

Distribution: Ladd formation, Baker member, *very abundant* and *characteristic*.

Discussion: This species is referred to *Aphrodina* with some misgivings. The material available for study is poorly preserved, and it has so far proved impossible to expose the hinge without some breakage of the teeth. The hinges so far uncovered seem identical with the hinge of *Aphrodina tippana* Conrad (the genotype) except that the anterior lateral tooth and socket of *A. tippana* are rather long and are striated, whereas these structures are shorter and apparently smooth in *A. arata*. These differences may prove important enough to justify at least subgeneric separation of the two species.

Aphrodina arata is especially characteristic of the Baker member of the Ladd formation in the Santa Ana Mountains. This species has not been reported from higher horizons, but within this member it is found at nearly every fossiliferous locality. The species was originally described from "Cottonwood Creek, Shasta County," a locality from which Gabb described a number of other species that in the Santa Ana Mountains are confined to the Baker sandstone.

Callista (*Aphrodina?*) *tenuis* Meek and Hayden (13, p. 188) is very much like *A. arata*, as is *Cytherea minutula* Stoliczka from the Ariyalur group of south India.

Superfamily MACTRIDAE
Family MACTRACEA

Genus CYMBOPHORA Gabb

CYMBOPHORA ASHBURNERII (Gabb)

Plate 49, figure 1

Mactra ashburnerii GABB, *1864*, Paleontology Calif., vol. 1, p. 153, pl. 22, fig. 127.—ARNOLD, *1909*, U. S. Geol. Survey, Bull. 396, p. 11, pl. 1, fig. 4.

Cymbophora ashburnerii GABB, *1869*, Paleontology Calif., vol. 2, pp. 181, 236, pl. 29, fig. 69.—WHITEAVES, *1903*, Canada Geol. Sur., Mesozoic Fossils, p. 374.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 212, pl. 5, fig. 6a.

Spisula ashburnerii PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 16, p. 298, pl. 26, figs. 4, 5, pl. 27, fig. 1.

Description: The following is a description of the left valve of this species: Chondrophore narrow and shallow, its floor being almost flush with the inner face of the hinge-plate; on the anterior border of the chondrophore is a very thin laminar tooth (accessory lamella?) which is separated from the posterior limb of the bifid cardinal by a very narrow slit; bifid cardinal tooth stout, limbs short; lateral teeth strong and situated close to the beaks.

Distribution: Ladd formation, Holz shale member, *rare;* Williams formation, *abundant.*

Discussion: The hinge of *Cymbophora ashburnerii* was figured by Gabb (supra) and his figure was reproduced by Packard (supra). In neither figure, however, is the dentition well represented. Stephenson (15, pl. 85, figs. 5, 6) has figured both valves of *Cymbophora trigonalis.* The dentition of this latter species appears to agree in every particular with the dentition of *C. ashburnerii* (the genotype) as revealed in this study. Stephenson's illustrations may serve as convenient examples of the dentition of this genus. The hinge of the left valve of *C. ashburnerii* is figured also in the present article.

CYMBOPHORA GABBIANA (Anderson)
Plate 49, figure 2

Mactra ashburnerii GABB, *1864* (in part), Paleontology Calif., vol. 1, p. 153.
Cymbophora ashburnerii WHITEAVES, *1879*, Canada Geol. Sur., Mesozoic Fossils, p. 141, pl. 17, fig. 8, *1903*, p. 373, *not* p. 374.
Mactra gabbiana ANDERSON, *1902*, Calif. Acad. Sci. Proc. (3), vol. 2, no. 1, p. 74, pl. 7, fig. 156.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia Spec. Pub. 3, p. 211.
Spisula gabbiana PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 16, p. 299, pl. 27, fig. 2.

Description: These notes describe the dentition of this species. In the right valve are two cardinal teeth joined at their dorsal ends; anterior cardinal tooth short, thin, very oblique, nearly parallel to the dorsal shell-margin; posterior cardinal likewise narrow and rather short, aligned almost vertically beneath the beak; chondrophore shallow, rather narrow, bounded dorsally by a thin oblique posterior lamina which includes between it and the shell-margin, a deep narrow cavity; posterior and anterior lateral teeth stout and rather short, situated close to the umbonal region of the shell, separated from the dorsal border by a deep socket; lunule and escutcheon undefined; lateral teeth very lightly striated; in the left valve is a single strong bifid (inverted V-shaped) anterior cardinal tooth separated from a narrow prominent laminar posterior tooth (accessory lamella?) by a deep narrow slit; chondrophore and subumbonal cartilage groove as in the right valve; anterior and posterior lateral teeth single and strong.

Distribution: Ladd formation, Holz member, *rare;* Williams formation, *very abundant.*

Discussion: The hinge of this species accords in all ways with that of *Cymbophora ashburnerii.* The species is doubtless a true *Cymbophora,* for the difference in sculpture separating the two forms is probably of no more than specific importance. Whiteaves (supra, p. 142) and Stewart (supra, p. 211) have called attention to the similarity of *C. gabbiana* to *Mactra tripartita* G. B. Sowerby of the Trichinopoly group of India.

Cymbophora gabbiana is especially well represented in the Williams formation. Few large collections may be made from this formation without getting abundant specimens of this species. The localities in the Holz shale from which the species is obtained are high in the section near the Holz-Williams contact. The fossil thus appears to be a good marker for the higher beds of the Upper Cretaceous of this region. The abundance of the species in certain localities in the Upper Cretaceous beds of the Simi Hills and the Santa Monica Mountains of southern California is probably of considerable significance in the correlation of these sections with that of the Santa Ana Mountains.

Class GASTROPODA
Subclass STREPTONEURA
Order TAENIOGLOSSA
Family NATICIDAE

Genus EUSPIRA Agassiz

EUSPIRA SHUMARDIANA (Gabb)
Plate 49, figure 3

Lunatia shumardiana GABB, *1864*, Paleontology Calif., vol. 1, pp. 106, 224, pl. 19, fig. 61.
Gyrodes compressus WARING, *1917*, Calif. Acad. Sci., Proc. (4), vol. 7, no. 4, p. 67, pl. 9, fig. 6.

Gyrodes californica PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 429, pl. 35, figs. 2, 2a.
Polinices shumardianus STEWART, *1927*, Acad. Nat. Sci. Philadelphia, Proc., vol. 78, p. 325, pl. 21, fig. 11.

Distribution: Ladd formation, Holz shale member, *common;* Williams formation, *?rare.*

Discussion: Packard (supra) in describing *Gyrodes californica* differentiated it from *G. compressus* Waring on the basis of the presence of a compressed subsutural zone in the latter species and its absence in the former. I have been able in this study to compare rather large collections of both species from the type localities of each. In any collection containing as many as half a dozen individuals, some specimens will show this depressed subsutural zone and some will not. In other respects no features upon which two separate species could be erected are discernible. The presence or absence of this depression is believed to be a feature of individual variation and of less than specific importance. Packard's species and Waring's species are therefore conspecific.

Gyrodes, to which this species has been referred, was established by Conrad in 1860 as a subgenus of *Natica*. Since that time, it has been treated as a distinct genus by nearly every worker who has had occasion to study the group. In reviewing *Gyrodes*, Meek remarked (13, p. 309):

> This genus is readily distinguished by its thin shell, wide open umbilicus, bounded by an angular more or less crenate margin and without a trace of callosity within, as well as by the truncated, slightly concave, and more or less wrinkled upper edge of its volutions—a combination of characters unknown in any other type of the Naticidae.

Every feature mentioned by Meek as characterizing *Gyrodes* is absent from the species here discussed, which can in no way be considered to be *Gyrodes*. The species accords well with *Polinices shumardianus* (Gabb) as figured by Stewart (supra). The species may be a *Polinices*, as Stewart suggests. Its narrow, almost closed umbilicus and the umbilical callosity that is truncate below the umbilicus and broad above are so similar to the characteristics of *Euspira* that I have tentatively referred the species to that genus.

Euspira shumardiana appears to be limited in the Santa Ana Mountains to the higher part of the Holz shale and to the Williams formation. The individuals from the latter horizon are much smaller than are those from the shale, but there seems no other basis for separating them.

Genus AMPULLINA Lamarck

AMPULLINA PACKARDI Popenoe, n. sp.

Plate 49, figures 4, 5

Amauropsis pseudoalveata PACKARD, *1922* (in part), Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 429, *not* plate 35, figs. 1a, 1b, 3.

Description: Shell small to medium in size, robust; spire rather short; body whorl very large, about seven-eighths the height of the shell; suture linear, bordered by a narrow sloping shoulder; whorl just below the shoulder markedly impressed by a shallow encircling sulcus; remainder of body whorl globular; anterior apertural margin only slightly produced; columella excavated anteriorly and covered with a smooth heavy callus that entirely conceals the umbilicus; anterior apertural margin rather broadly rounded with a conspicuous fasciole; aperture narrow posteriorly; ornamentation of fine growth-lines with development occasionally of fine, narrow, regularly spaced axial lines.

Holotype: California Inst. Technology Invert. Paleo. Cat. no. 3453.

Dimensions of holotype: Length, 24.1 mm., diameter of last whorl, 20.8 mm.

Distribution: Ladd formation, Holz shale member, *common* and *characteristic.*

Discussion: Doctor Packard evidently included this species in his description of "*Amauropsis*" *pseudoalveata*, which represents a distinct species and is confined in its occurrence in the Santa Ana Moun-

tains to the horizon of the Baker member of the Ladd formation.

Ampullina packardi is distinguished from *A. pseudoalveata* by these features: *A. packardi* has a narrow, sloping shoulder to the whorl, a pronounced encircling sulcation below the shoulder, and a rather short and rounded anterior apertural margin. *A. pseudoalveata* has a rather broad, flat or channeled shoulder to the whorl, is nearly flat to slightly concave below the shoulder, has a produced and peaked anterior apertural margin, and averages at least one-half again larger than *A. packardi*. The difference in stratigraphic position of the two species has been outlined above.

A. packardi may be a descendant of *A. pseudoalveata*, for its immature members resemble the individuals of the larger and geologically older species considerably in general appearance. There is but little doubt that the two species are closely related.

Family TURRITELLIDAE

Genus TURRITELLA Lamarck

TURRITELLA CHICOENSIS Gabb

Plate 49, figures 7, 9, 10

Turritella chicoensis GABB, *1864*, Paleontology Calif., vol. 1, p. 133, pl. 21, fig. 91.—STEWART, *1927*, Acad. Nat. Sci. Philadelphia, Proc., vol. 78, p. 348, pl. 21, fig. 1.

Turritella pescaderoensis? ARNOLD, *1908*, U. S. Nat. Mus., Proc., vol. 34, p. 358, pl. 31, fig. 7.—PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 12, pp. 142, 143, 145, 148.

Distribution: (a) Dwarf form, typical—middle and upper but not uppermost horizons of the Holz shale member, Ladd formation, *abundant* and *characteristic*.

(b) Giant form, round-whorled—uppermost horizon of the Holz shale member, Ladd formation, *very abundant* and *characteristic*.

(c) Giant form, flat-whorled—Williams formation, *occasional*.

Discussion: *Turritella chicoensis*, one of the most persistent and abundant fossils of the upper part of the Holz shale, was selected by Packard as the "zone fossil" of the shale portion of the Cretaceous section of the Santa Ana Mountains. This species appears in three well-characterized zones, each zone bearing a distinct mutation of the species. The lowermost zone is that of the more shaly beds in the upper half of the Holz shale, extending from about the middle part of the shale section, to within two hundred feet of the top of this member. The second zone includes a series of sandy beds with a probable maximum thickness of two hundred feet, at the very top of the Holz shale member. The third zone is that of the uppermost beds of the Williams formation.

The mutation of *Turritella chicoensis* characteristic of the lowermost zone outlined above is a medium-sized shell that is indistinguishable from typical *T. chicoensis* from the type locality in the canyon of Chico Creek, Butte County, California. This shell has rounded whorls, a depressed suture, four or five raised, rather widely spaced spirals on each whorl, and a narrow unornamented band on each side of the suture. This form is figured on plate 49, figure 7. The mutation of *T. chicoensis* found in the zone at the top of the Holz shale is a giant form, reaching in some individuals a length of 100 mm., or twice the length of the largest specimens of the species found in the zone below. Except for their robust size, these giants do not differ materially in either form or sculpture from the typical dwarf variety of the species. The third mutant of this species is found in the uppermost beds of the Williams formation. This mutant is a giant form that has developed a flat-sided whorl in many individuals due to the formation of strong spirals close to the suture line on both sides of the suture. This change in sculpture and whorl-shape would justify the description of this mutant as a distinct species were it not for the fact that fully one-half of the giant individuals appearing at this horizon are exactly like the round-whorled giants found in the highest beds of the Holz shale. Some of these flat-

sided mutants from the Williams formation are immense—perfect individuals in some instances equaling or exceeding a length of 100 mm. and being correspondingly robust.

TURRITELLA IOTA Popenoe, n. sp.
Plate 49, figure 8

Description: Shell of medium size, rather slender: whorls shallowly concave along the posterior four-fifths of the whorl, the sides of the whorl diverging to a definite keel or shoulder near the anterior suture, thence sloping abruptly from the keel inward to the suture; sculpture of three or four strong beaded spirals, separated by numerous fine spirals developed between the principal ones; aperture almost quadrate.

Holotype: California Inst. Technology Invert. Paleo. 3457.

Dimensions of holotype: Length (incomplete), 37.4 mm., diameter, 8.6 mm.

Distribution: Ladd formation, Holz member, *rare.*

Discussion: This *Turritella* is found rarely at a horizon very low in the Holz shale member, a short distance stratigraphically above the contact between the Holz and Baker members of the Ladd formation.

This species resembles somewhat *Turritella whiteavesi* Anderson and Hanna but differs from it in the pronounced keel on the anterior part of the whorls and on the slightly concave outline of the whorl posterior to this keel.

TURRITELLA OSSA Popenoe, n. sp.
Plate 49, figure 6

Description: Shell small, rather slender; apical angle about 18°; whorls gently convex anteriorly, concave posteriorly, slightly inflated just posterior to the suture, constricted at the suture; suture linear; side and base of whorl meeting in a smooth rounded curve; base oblique, gently convex, ornamented with a few very faint spiral lines most prominent at the juncture of the side and base of the whorl; aperture quadrate, slightly higher than wide; sculpture of growth-lines only, or of very faint spiral lines in addition to the growth lines; growth-lines inclined away from the aperture on the posterior part of the whorl, toward the aperture on the anterior part of the whorl, and crossing the base in almost a straight line.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3458.

Paratype: California Inst. Technology, Invert. Paleo. Cat. no. 3459, 3460.

Dimensions of holotype: Length (incomplete), 20.0 mm., diameter, 9.4 mm. Dimensions of a paratype: Length, 26.0 mm., diameter, 9.3 mm.

Distribution: Ladd formation, Holz shale member, *common.*

Discussion: *Turritella ossa* is confined in its distribution almost entirely to a number of scattered localities in the upper half of the Holz shale. It is quite abundant at these localities.

The species differs from any other California Cretaceous *Turritella* I have seen in the shape of its whorl, and in its very faint or obsolete sculpture. It is apparently represented in the Upper Cretaceous beds of the Simi Hills, Los Angeles County, California. I know of no other occurrence of the species.

REFERENCES

1. CONRAD, T. A., *Acad. Nat. Sci. Philadelphia, Jour.*, vol. 4, p. 289, 1860.
2. ——— *Acad. Nat. Sci. Philadelphia, Proc.*, vol. 16, p. 213, text fig., 1864.
3. ——— *Am. Jour. Conchology*, vol. 6, pp. 72, 73, 1870–1871.
4. COSSMAN, M., *Coquilles Fossiles de l'Eocène des Environs de Paris*, p. 113, 1886.
5. CLARK, B. L., Pelecypoda from the marine Oligocene of western North America: *Univ. Calif. Dept. Geol. Sci., Bull.*, vol. 15, no. 4, 1925.
6. CLARK, W. B., and MARTIN, G. C., Eocene deposits of Maryland: *Maryland Geol. Survey*, p. 171, 1901.
7. DALL, W. H., The Tertiary fauna of Florida: *Wagner Free Inst. Science, Trans.*, vol. 3, pt. 4, p. 604, 1898.
8. ——— *U. S. Nat. Mus., Proc.*, vol. 26, p. 933, 1903.
9. GABB, WILLIAM MORE, *California Geol. Survey, Paleontology*, vol. 1, 1864.
10. GARDNER, JULIA, The molluscan fauna of the Alum Bluff group of Florida:

U. S. Geol. Survey, Prof. Paper 142-A, p. 22, 1926.

11. HOLZAPFEL, E., Die Mollusken der Aachener Kreide: *Paleontographica*, Band 35, 1889.
12. JUKES-BROWN, A. J., On the genera of Veneridae represented in the Cretaceous and older Tertiary deposits: *Malac. Soc. London, Proc.*, vol. 8, 1908.
13. MEEK, F. B., A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: *U. S. Geol. Survey of the Territories*, vol. 9, 1876.
14. PALMER, K. W., The Veneridae of eastern America, Cenozoic and Recent: *Paleont. Americana*, vol. 1, pt. 5, p. 6, 1927.
15. STEPHENSON, L. W., The Cretaceous formations of North Carolina: *North Carolina Geol. and Econ. Survey*, vol. 5, 1923.
16. ——— Upper Cretaceous fossils from Georges Bank (including species from Banquereau, Nova Scotia): *Geol. Soc. America, Bull.*, vol. 47, no. 3, 1936.
17. STEWART, R. B., Gabb's California fossil type gastropods: *Acad. Nat. Sci. Philadelphia, Proc.*, vol. 78, 1927.
18. ——— Gabb's California Cretaceous and Tertiary type lamellibranchs: *Acad. Nat. Sci. Philadelphia, Spec. Pub.* 3, 1930.
19. STOLICZKA, FERDINAND, The Cretaceous fauna of southern India, the Pelecypoda: *Mem. Geol. Survey India, Paleontologia Indica*, ser. 6, no. 3, 1871.
20. WHITEAVES, J. F., *Canada Geol. Survey, Mesozoic Fossils*, vol. 1, 1876–1903.
21. WOODS, HENRY, A monograph of the Cretaceous Lamellibranchia of England: *Mon. Paleontographical Soc.*, vol. 1, 1899–1903, vol. 2, 1904–13.

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NOTICE

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A NEW PENNSYLVANIAN CEPHALOPOD FAUNA FROM OKLAHOMA

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ABSTRACT

In this paper there is described and illustrated a new cephalopod fauna which came from concretions in the Coffeyville formation, just above the Dawson coal, near Collinsville, Oklahoma. The fauna consists of two new species of nautiloids (referable to the genera *Coloceras* and *Metacoceras*), eight new species of ammonoids (referable to *Gastrioceras*, *Prothalassoceras*, *Schistoceras*), and two new genera (*Eudissoceras* and *Bisatoceras*). No older ammonoids are known from the Missouri series of the Mid-Continent region, and this fauna contains the oldest known representatives of *Prothalassoceras* and probably *Schistoceras*. The specimens are remarkably well preserved and reveal the nature of the surface ornamentation and the shape of the sutures throughout ontogenetic development.

Some three years ago Mr. John M. Ware of Tulsa, Oklahoma, called our attention to the fact that large black concretions containing goniatites had been uncovered in strip pits near Collinsville, Oklahoma. During the summer of 1934, Owen made several trips to these strip pits and obtained more than two hundred well-preserved cephalopods. Since that time Dr. L. M. Cline has made an extensive collection from the same locality, which he kindly placed at our disposal, and Mr. D. J. Jones and Dr. N. D. Newell have loaned us additional specimens from the same place. Indebtedness for all these favors is acknowledged.

The following concise discussion of the occurrence of the Collinsville goniatites has kindly been prepared for us by John M. Ware and Robert H. Dott.

The goniatite collections under consideration came from limy concretions occurring throughout a zone of black shale 5 feet 7 inches thick, immediately overlying the Dawson coal, in strip pits in the S½ sec. 32, T. 22 N., R. 14 E., near Collinsville, Oklahoma. A section of the rocks in which the goniatites occur is represented by figure 1, which is self-explanatory.

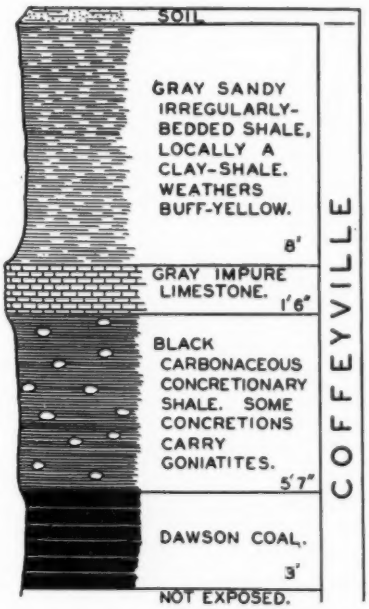


FIG. 1—Section at north end of strip pits south of Collinsville, Oklahoma. By John M. Ware, March 16, 1936.

Concretions are commonly present throughout the outcrops of the black shale in this

general vicinity, but they are only locally fossiliferous. In the south end of the pits from which the collections came, two concretions out of three yield fossils, whereas in the north end of the mined area, nine out of ten are barren. Essentially the same section is exposed near Dawson, Oklahoma, but there the concretions are reduced to mere nodules generally less than 2 inches in diameter and are seemingly barren of fossils.

On the geologic map of Oklahoma, compiled by H. D. Miser in 1923 and 1924 and published by the U. S. Geological Survey in 1926, the top of the Dawson coal is mapped as the top of the Nowata shale south of the city of Nowata. This procedure is in accord with the views of Ohern (2), who correlated the Dawson coal with the Lenapah limestone, which by definition (1) marks the top of the Nowata shale. In northern Oklahoma, the Lenapah limestone is overlain by the Coffeyville formation, and in accordance with the classification used on the state map, the goniatite-bearing beds at the Collinsville locality are the base of the Coffeyville, since they immediately overlie the Dawson coal.[1]

The Lenapah limestone is now thought to be equivalent to a thin coquinoid limestone that crops out in the area between Mounds and Collinsville, and which, in the vicinity of Collinsville, occurs approximately 180 feet below the Dawson coal. The typical Des Moines genera *Mesolobus* and *Prismopora* are common in both the Lenapah and its southern equivalent.

Recent field work has shown that the Dawson coal lies in the middle of the Seminole formation. In the vicinity of Collinsville this formation is composed of three members—a lower sandstone, a middle shale, containing the Dawson coal, and an upper sandstone—all of which are well developed here.

On the basis of the revised correlations, the base of the Coffeyville formation is approximately 180 feet below the Dawson coal in the vicinity of Collinsville, and the Coffeyville contains the Seminole, together with 50 feet of underlying shale in its lower part. This places the goniatite-bearing beds 180 to 185 feet above the base of the Coffeyville formation rather than at its base.

[1] In a preliminary report by Miller and Owen on the Collinsville cephalopods (Geol. Soc. of Am. Proc. for 1935, p. 369, abstract) the containing beds were inadvertently classed with the underlying Dawson coal and referred to the Nowata formation.

Perhaps the most noteworthy character of the fauna under consideration is that it consists almost exclusively of ammonoids. The collections contain one pelecypod, seven nautiloids, and several hundred ammonoids. Presumably the bottom of the sea in which the containing beds accumulated was inhospitable, but we are unable to explain satisfactorily the apparent dearth of nautiloids in a Pennsylvanian sea in which ammonoids were extremely abundant.

In a few of the many broken specimens collected, some of the camerae had not been entirely filled with stony material but instead were lined with inwardly projecting crystals of calcite and were filled with black viscous petroleum. The adapical end of the preserved part of the outer volution of the specimen represented by figure 1 on plate 51 is part of such a crystal-lined petroleum-filled cavity.

Another peculiarity of the specimens obtained is the excellent state of preservation. Many of the specimens can be prepared quite readily to reveal the nature of the surface ornamentation and the shape of the sutures throughout ontogenetic development. It has been known for a long time that the inner surface or layer (called "Runzelschicht" by certain German paleontologists and by John M. Clarke) of certain De-

vonian ammonoids belonging in the genera *Tornoceras*, *Manticoceras*, *Timanites*, and others, is finely papillose. In none of the numerous Carboniferous ammonoids that we have studied previously have we noted a trace of the "Runzelschicht," but it is well preserved in many of the specimens under consideration, and we have found it in all the ammonoid genera represented and in one genus of nautiloids, *Metacoceras*.

This fauna is more than ordinarily interesting because it is the oldest ammonoid fauna known from the Missouri series of the Mid-Continent region. As might be expected, it consists of a mixture of elements that are typical of the Des Moines series and those that have always been regarded as being characteristic of younger horizons. With the exception of *Prothalassoceras* and *Schistoceras*, all the genera represented, including the two new genera *Eudissoceras* and *Bisatoceras*, occur also in the Wewoka formation of the Des Moines series, and three of the genera (*Coloceras*, *Metacoceras*, and *Castrioceras*) are abundant at several horizons in the Des Moines as well as in younger beds. *Schistoceras*, on the contrary, has always been thought to be characteristic of the uppermost Pennsylvanian, and the form we are describing below is perhaps the oldest representative of the genus known. Also, *Prothalassoceras* was for a long time believed to be diagnostic of the Permian, and although it has been reported previously from the uppermost Pennsylvanian (Gaptank formation), we did not expect to find it in beds as old as the Coffeyville formation. It should perhaps be pointed out in this connection that the Coffeyville species of both *Prothalassoceras* and *Schistoceras* are primitive representatives of the genera, but they are hardly as primitive as might be expected from such an old formation.

SYSTEMATIC DESCRIPTIONS

COLOCERAS RETICULATUM Miller and Owen, n. sp.

Plate 50, figures 15–18

Conch subglobular, nautiliconic, and moderately large—phragmacone (which in large specimens consists of at least two and one-half volutions) attains a diameter (measured across the umbilicus) of at least 42 mm. and a maximum height and width of conch of at least 25 mm. and 38 mm., respectively. Living chamber about one-half volution in length.

Extreme adapical portion of conch circular (or essentially so) in cross section, but before conch has completed half a volution it is distinctly depressed dorsoventrally, and is subelliptical in cross section, its dorsal side being less strongly arched than its ventral. As soon as conch completes one volution a dorsal impressed zone is developed, but throughout ontogenetic development it remains rather shallow. At maturity whorls are reniform in cross section and about two-thirds as high as wide.

Umbilicus perforate and moderately large, its diameter slightly more than one-half that of specimen. Umbilical perforation oval and rather small, about $1\frac{1}{4}$ mm. wide and 2 mm. long. Umbilical shoulders rounded and indistinct. Umbilical walls broadly rounded.

Surface of adapical portion of conch reticulate, marked by fairly prominent longitudinal and transverse lirae. Long-

itudinal lirae becoming somewhat less prominent during ontogenetic development but being retained on the dorsolateral portions of the test (umbilical walls) at least until full maturity. Ventral portions of the test of mature specimens marked by numerous very fine rather inconspicuous longitudinal lirae. Transverse lirae, growth lines, straight, or essentially so, on the extreme adapical portion of the conch, but soon forming a low rounded salient on the dorsal side of the conch and a distinct sinus on the ventral side; at maturity they form a broad, deep, more or less depressed V-shaped but rounded ventral sinus, a hyponomic sinus. Traces of both the increments of growth and the fine longitudinal lirae readily discernible on well-preserved internal molds.

Sutures of first volution are simple circles directly transverse to the long axis of the conch; later sutures form broad shallow rounded dorsal lobes where they cross the impressed zone, each dorsal lobe divided medianly by a small subangular annular lobe, which appears before the dorsal lobe is formed; the sutures otherwise, even at full maturity, are essentially straight and directly transverse. Camerae moderate in length, about fifteen to the volution at least during early maturity. Septa moderately convex apicad, but, as in modern *Nautilus*, having next to the dorsum a small but prominent subangular adapical inflection, which gives rise to the annular lobe of the sutures.

Siphuncle small, circular in cross section, orthochoanitic in structure, and subcentral in position but distinctly nearer the venter than the dorsum—it appears to be nearer the venter during adolescence than at maturity. Relative length of septal necks and connecting rings not determined.

Remarks: The above description is based on six specimens, but only one of them (pl. 50, fig. 17) is fairly complete. It is small and immature. Congeneric forms are not rare in the Mississippian, Pennsylvanian, and Permian of both Europe and America; although all of them are much alike, *Coloceras reticulatum* does not seem to be particularly close to any described form. Its relatively slender conch and the peculiar surface ornamentation of its test differentiate it from all known species.

Occurrence: Concretions in Coffeyville formation, just above Dawson coal, about three-quarters of a mile south of Collinsville, Oklahoma.

Syntypes: The specimens represented by figures 15 and 17 on plate 50 and one unfigured specimen are in the private collection of John Britts Owen, of Clinton, Missouri; the rest of the syntypes are at the State University of Iowa, numbers 2000 (pl. 50, figs. 16 and 18) and 1999 (unfigured specimens).

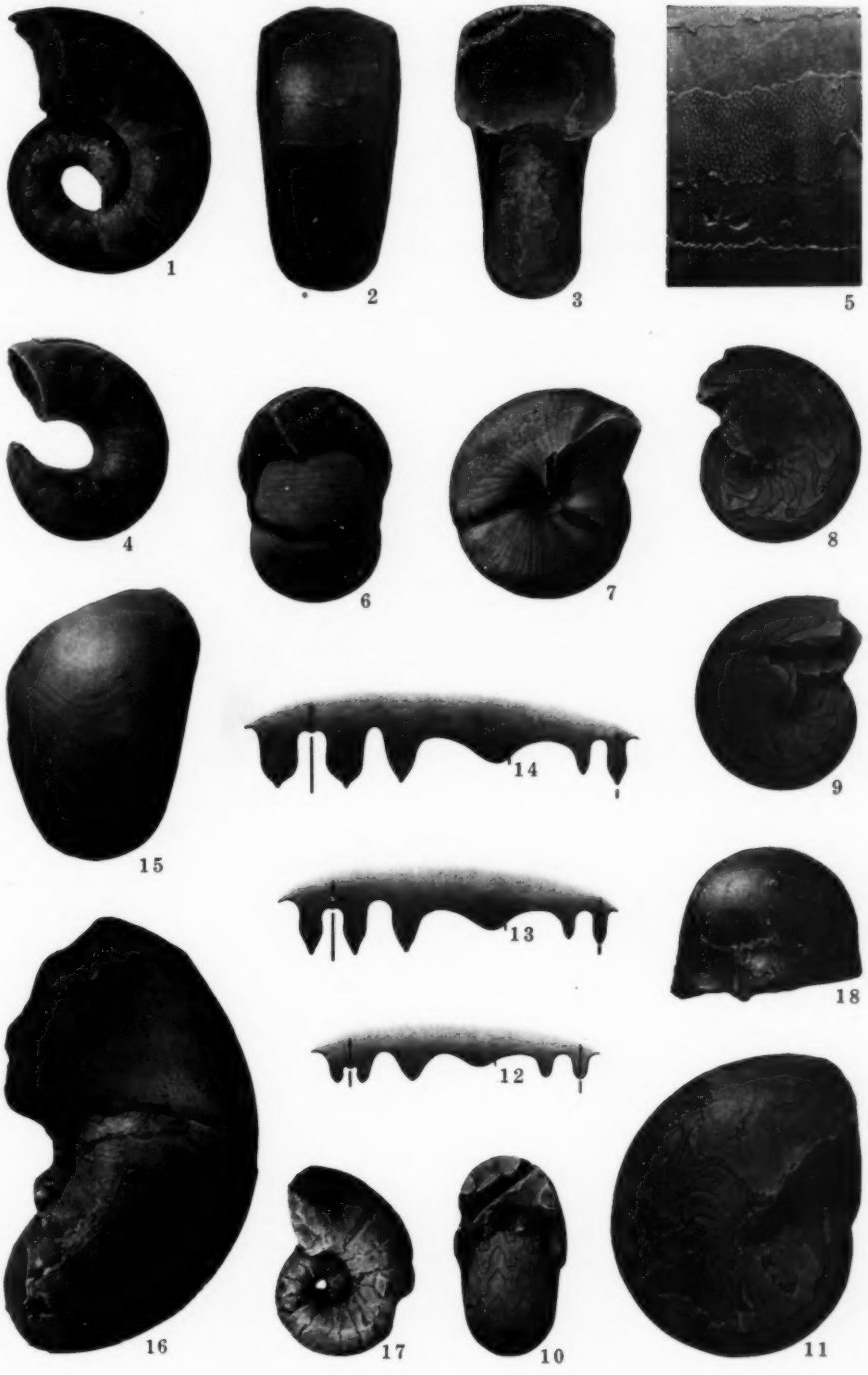
EXPLANATION OF PLATE 50

All specimens illustrated on this plate came from concretions in the Coffeyville formation just above the Dawson coal, about three-quarters of a mile south of Collinsville, Oklahoma.

FIGS. *1–5*—*Metacoceras vagans* Miller and Owen, n. sp. Three views of the holotype, ×1½; the adapical portion of the same specimen, ×2; and an enlargement of the inner surface of the test (a portion of the umbilical wall of the outer volution of the holotype) showing the peculiar ornamentation and the areas of attachment of septa, ×15. (p. 407)

6–14—*Bisatoceras primum* Miller and Owen, n. sp. *6*, *7*, An immature syntype, ×4; *8–11*, two mature syntypes, ×2; and diagrammatic representations of the sutures at diameters of 3.3 mm., 7.0 mm., and 17.7 mm.—*12* is ×7½; *13*, which is based on the same specimen as *12*, is slightly less than ×4; and *14*, which is based on the specimen represented by *11*, is ×2. (p. 417)

15–18—*Coloceras reticulatum* Miller and Owen, n. sp. Three of the syntypes (*16—18* represent the same specimen); all but *16*, which is ×2, are ×1¼. (p. 405)



Miller and Owen, Pennsylvanian Cephalopods

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METACOCERAS VAGANS Miller and Owen, n. sp.

Plate 50, figures 1–5

The genus *Metacoceras*, which is so abundant in most Pennsylvanian cephalopod faunas, is represented by only one specimen, which is remarkably well preserved, and appears to be unique. We propose the name *Metacoceras vagans* for it.

Holotype, which represents only adapical one and one-half volutions of phragmacone, about 27 mm. in diameter; adoral end of conch about 14 mm. wide and 11 mm. high. Extreme adapical portion of conch circular, or essentially so, in cross section; lateral diameter increasing more rapidly than dorsoventral diameter until the conch is distinctly depressed dorsoventrally, and subelliptical in cross section, its dorsal side being somewhat flattened, at one-half volution. Within the next quarter volution the flattening of the dorsal side becomes progressively more and more pronounced, and umbilical shoulders are developed. After the conch has completed one full volution a dorsal impressed zone is developed, but it remains shallow, and even at the adoral end of the holotype the impressed zone is only a little more than 1 mm. deep and about 5 mm. wide. Before the conch has completed one full volution, it shows a distinct tendency to become progressively flattened laterally and ventrally, as well as dorsally, and therefore it gradually becomes subrectangular in cross section, with its lateral sides converging slightly ventrad.

Extreme adapical portion of conch is marked by indistinct longitudinal lirae and by transverse growth lines. The longitudinal lirae are confined to the very "tip" of the conch, and the rest of the adapical portion of the conch is marked by only the growth lines, which, however, are quite distinct. After conch has completed about three-fifths of a volution, it is very slightly constricted, and immediately orad of this constriction a row of low rounded nodes appears on each of the lateral sides of the conch. At first these nodes are lateral in position (as in *Endolobus*), but as the conch develops ventrolateral shoulders, the nodes become ventrolateral in position, and they remain so. On internal mold of conch there is, in addition to the nodes, a small rounded ridge or raised line along the venter.

Umbilicus perforate and rather large, diameter about four-ninths that of the specimen. Umbilical perforation oval; about 3 mm. wide and 5 mm. long. Umbilical shoulders on adoral portion of holotype subangular.

Test thin; even on dorsal portion of holotype it appears to be less than one-half mm. thick. Holotype exceptionally well preserved. Inner surface of test finely papillose, like that of the "Runzelschicht" of goniatites (pl. 50, fig. 5); papillae apparently trending longitudinally on the dorsal zones and transversely on the ventral zones.

On adapical quarter volution of holotype camerae are rather long and along the venter the distance between successive sutures is equal to about one-half height of conch. About the beginning of the second quarter volution of the conch, the camerae abruptly become much shorter, so that along the venter their length is equal to only about one-third height of conch. Following this, their relative length remains fairly constant, but becomes slightly greater in proportion to the height of the conch as the conch becomes more and more strongly depressed; at the adoral end of the holotype there are about two and one-half camerae in a length, measured along the venter, equal to the height of the conch.

The first sutures are essentially simple circles, but before the conch has completed one-half volution, broad shallow rounded lateral lobes are developed. Then, when the conch has completed one full volution and an impressed zone is developed, the sutures form rounded dorsal lobes as they cross the impressed zone; and on the adoral half volution of

the holotype, broad very shallow broadly rounded lobes are developed on the ventral side of the conch. On the adoral portion of the holotype each suture then forms a broad shallow rounded lobe on the ventral, the lateral, and the dorsal sides of the conch, and these are separated by subangular saddles. The part of the suture forming the dorsal side of the lateral lobe continues to curve orad across the umbilical wall, and the subangular dorsolateral saddle centers on the umbilical seam rather than on the umbilical shoulder; there is, however, a marked decrease in the amount of adoral curvature of the sutures on the umbilical shoulder.

Siphuncle small, circular in cross section, and presumably orthochoanitic in structure. In extreme adapical part of conch it is central or nearly so in position, but it soon migrates to a subventral position, where it remains. At adoral end of holotype, siphuncle is about 1 mm. in diameter, and its center is about $3\frac{1}{2}$ mm. from venter and $6\frac{1}{2}$ mm. from dorsum.

Remarks: In typical representatives of the genus *Metacoceras*, like *M. sangamonense* (Meek and Worthen), the genotype, both the ventral and lateral sides of the conch are slightly concave, but in *M. vagan*: the ventral and lateral sides, though almost straight, are slightly convex even at the adoral end of the holotype. However, it is quite possible that the holotype and only known representative of this species is an immature specimen and that it would have developed more nearly typical characters as it attained full maturity. If this holotype is immature, adequate specific comparisons are not possible, for we do not know the mature characters of the species; if, on the contrary, it is a mature specimen, the shape of its conch and the relatively slight sinuosity of its sutures will serve to distinguish it from other congeneric forms. The genus *Metacoceras* is known to range stratigraphically from the Pottsville (of Ohio) at least into the Lower Permian (of Kansas, Russia, and Sumatra?), and therefore the occurrence of a representative of this genus in the Coffeyville formation is of no particular stratigraphic significance.

Occurrence: Concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma.

Holotype: Private collection of John Britts Owen, of Clinton, Missouri.

Genus EUDISSOCERAS Miller and Owen, n. gen.

In almost all of the Pennsylvanian goniatites whose sutures form a total of eight primary lobes, the ventral lobe is

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EXPLANATION OF PLATE 51

All specimens illustrated on this plate came from concretions in the Coffeyville formation just above the Dawson coal, about three-quarters of a mile south of Collinsville, Oklahoma.

FIGS. *1–3*—*Gastrioceras jonesi* Miller and Owen, n. sp. Three views of the holotype, ×1—same specimen as text figure 3. (p. 413)

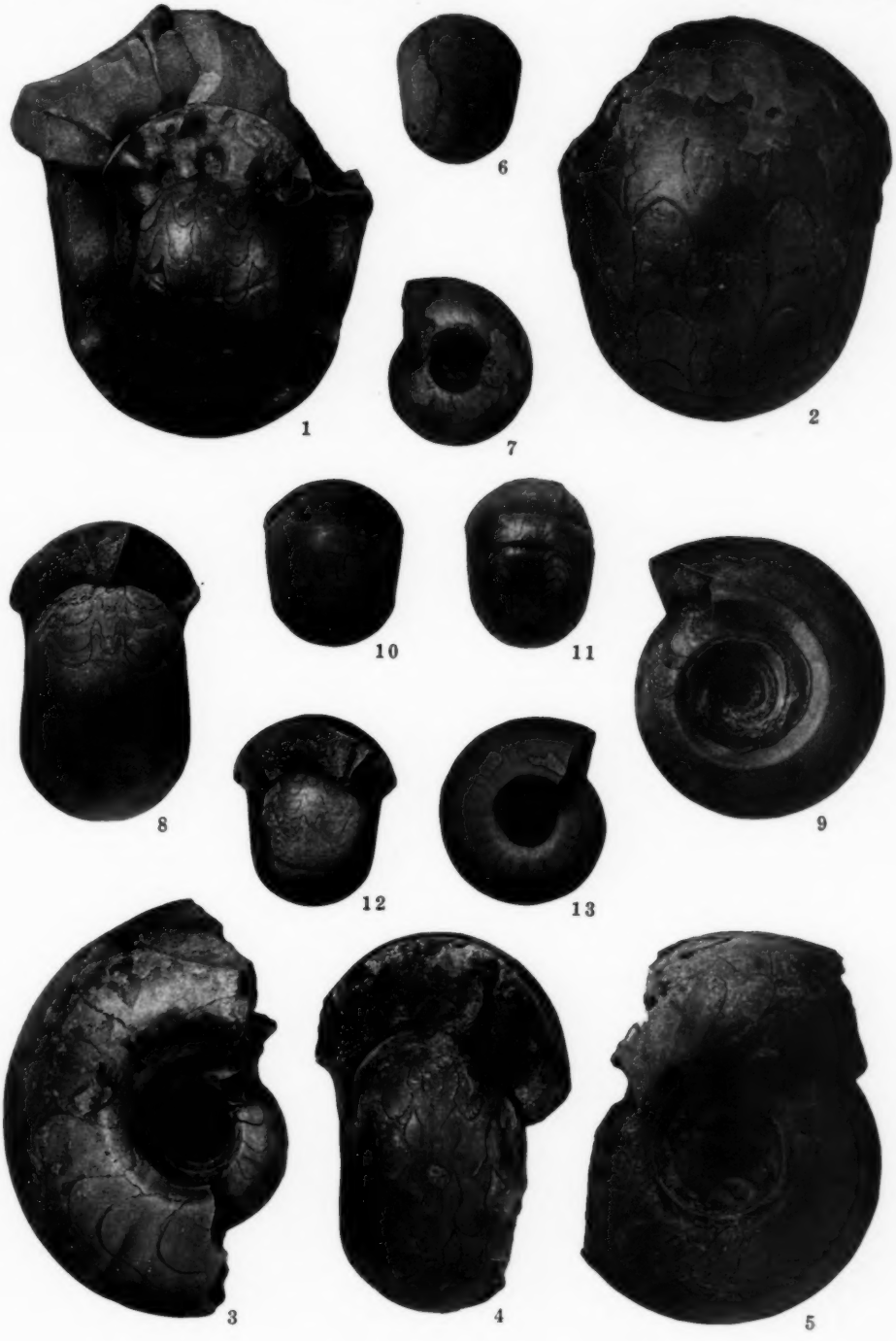
4, 5—*Gastrioceras clinei clinei* Miller and Owen, n. sp. and n. var. Two views of the holotype, ×$\frac{3}{4}$—same specimen as text figure 2F. (p. 410)

6–9—*Gastrioceras clinei warei* Miller and Owen, n. sp. and n. var. *6, 7*, Two views of a paratype, an early mature specimen, ×2—same specimen as text figure 2A; and *8, 9*, two views of the holotype (of the variety *warei*), ×1—same specimen as text figure 2E. (p. 410)

10—*Gastrioceras jonesi* Miller and Owen, n. sp. Ventral view of a paratype, an early mature specimen, in which the sutures are abnormally far apart, ×2—same specimen as text figure 2C. (p. 413)

11—*Gastrioceras clinei clinei* Miller and Owen, n. sp. and n. var. Ventral view of a paratype, an early mature specimen, in which the sutures are abnormally close together. ×2. (p. 410)

12, 13—*Gastrioceras clinei warei* Miller and Owen, n. sp. and n. var. Two views of a paratype, an early mature specimen, ×2. (p. 410)



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unequally trifid. However, the collections we are studying contain three specimens that represent a species in which during maturity, at least, the ventral lobe of the sutures is clearly bifid. This characteristic together with the general physiognomy of the conch and the sutures seems to us to eliminate these specimens from all existing genera to which they might otherwise be referred, and therefore we are establishing a new genus for them, which we propose to call *Eudissoceras*.

The new genus (genotype, *E. collinsvillense*) can be diagnosed as follows: Conch sublenticular and ammoniticonic. Umbilicus open but moderately small. Growth lines form ventral and lateral sinuses and ventrolateral and dorsolateral salients. Umbilical shoulders smooth at maturity but nodose during adolescence. Each mature suture forms a large more or less V-shaped but bifid ventral lobe and on either side of it a somewhat smaller rounded first lateral saddle, a moderately large and deep rounded first lateral lobe, a relatively low rounded second lateral saddle (which centers outside the umbilical shoulder), and a small rounded lobe on the umbilical wall, the prongs of the ventral lobe, like the secondary saddle which separates them, small and rounded. Siphuncle ventral and marginal in position.

The paleontological collections of the State University of Iowa contain numerous representatives of an undescribed species of this genus from the Lower Pennsylvanian (Wewoka?) of Oklahoma.

Eudissoceras seems to be closer to *Reticuloceras* than to any other genus known to us, but it differs from that form in that the ventral lobe of its sutures is bifid rather than trifid and its conch is nonreticulate and is differently shaped.

EUDISSOCERAS COLLINSVILLENSE
Miller and Owen, n. sp.
Plate 52, figures 4–7

Conch, which at maturity consists of at least four or five volutions, is ammoniticonic, sublenticular, and moderate in size, attaining a maximum diameter (measured across the umbilicus) of at least 14 mm. and a maximum height and width of conch of at least 7½ or 8 mm. During adolescence conch is subglobular in shape and early volutions are much wider than high and very broadly rounded ventrally. However, dorsoventral diameter increases much more rapidly than lateral diameter, and at adoral end of largest of the syntypes conch is about as high as wide and in general is narrowly rounded ventrally, though on the internal mold, at least, there is a narrow flattened zone along the venter. Living chamber at least half a volution in length. Umbilicus moderately small, and it becomes relatively smaller during ontogenetic development —at maturity its diameter is equal to only about one-fourth that of specimen. Umbilical shoulders rounded during adolescence but subangular at maturity. Umbilical walls steep during maturity and almost flat.

Test thin and its inner surface or layer ("Runzelschicht") is finely papillose. On innermost volutions of conch umbilical shoulders are smooth, but after conch has completed one or two volutions umbilical shoulders become distinctly nodose and each bears twenty to twenty-five rounded transversely elongate nodes or short ribs (pl. 52, fig. 6). As full maturity is attained these nodes or ribs gradually disappear and the umbilical shoulders become slightly flared. During adolescence each volution of internal mold of conch is marked by about four sinuous transverse rounded constrictions, which form ventral and lateral sinuses and ventrolateral and dorsolateral salients. The growth lines, which are rather prominent, appear to be essentially parallel to these constrictions, and the umbilical nodes seem to be formed to a large extent by the fasciculation of the growth lines. As the conch approaches full maturity, the constrictions disappear and the growth lines become more and more strongly sinuous. On the adoral por-

tion of the largest of the syntypes each growth line forms a deep narrowly rounded ventral sinus and on either side of it a very prominent rather narrowly rounded ventrolateral salient, a broad relatively shallow broadly rounded lateral sinus, a similar but smaller dorsolateral salient (which centers outside the umbilical shoulder), a broad shallow subangular sinus centering on the umbilical shoulder, and a very shallow rounded salient on the umbilical wall. Even on the adoral portion of the largest of the syntypes the increments of growth show a distinct tendency toward fasciculation (pl. 52, fig. 5).

Two of the three syntypes apparently do not retain their sutures, but on the penultimate volution of the largest of the syntypes, the external sutures can be seen quite clearly. Each of these forms a large more or less V-shaped but bifid ventral lobe and on either side of it a somewhat smaller asymmetrical rounded first lateral saddle, a moderately large and deep rather broadly rounded first lateral lobe, a relatively low asymmetrical broadly rounded second lateral saddle (which centers outside the umbilical shoulder), and a smaller shallow, broadly rounded lobe on the umbilical wall. The prongs of the ventral lobe and the secondary saddle which separates them are small and rounded (pl. 52, fig. 7). The siphuncle is small, and it is ventral and marginal in position.

Observations: Since this species is the first representative of the new genus to be described, specific comparisons would be superfluous. The most distinctive characteristics of this form are its primitive sutures in which the ventral lobe is bifid rather than irregularly trifid, its adolescent ribs, and its sinuous fasciculate growth lines.

Occurrence: Concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma, where it is rather rare.

Syntypes: All three of the syntypes are in the private collection of John Britts Owen, of Clinton, Missouri.

GASTRIOCERAS CLINEI Miller and Owen, n. sp.
Plate 51, figures 4–9, 11–13

Conch subglobular, ammoniticonic, and moderately large—phragmacone attains a maximum diameter (measured across the umbilicus) of at least 75 mm., and a maximum height and width of conch of at least 27 mm. and 47 mm., respectively. In early mature specimens, at least, living chamber is slightly more than one volution in length. Conch depressed dorsoventrally so that at maturity whorls, which are helmet-shaped in cross section, are some two or three times as wide as high. Umbilicus open and rather large—its diameter ranges from about one-third to about one-half that of specimen. Umbilical shoulders narrowly rounded to subangular; umbilical walls steep.

Umbilical shoulders bear a few small but rather prominent longitudinal lirae, and on at least some specimens faint

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FIG. 2—Diagrammatic representations of external sutures.
A, *Gastrioceras clinei warei* Miller and Owen, n. sp. and n. var., at a diameter of 9.8 mm. (early maturity), ×10—same specimen as figures 6 and 7 on plate 51.
B, *Gastrioceras retiferum* Miller and Owen, n. sp., at a diameter of 8.7 mm. (early maturity), ×12—same specimen as figures 8–10 on plate 52.
C, *Gastrioceras jonesi* Miller and Owen, n. sp., at a diameter of 11.4 mm. (early maturity), ×9—same specimen as figure 10 on plate 51.
D, *Gastrioceras clinei clinei* Miller and Owen, n. sp. and n. var., at a diameter of 10.1 mm. (early maturity), ×12.
E, *Gastrioceras clinei warei* Miller and Owen, n. sp. and n. var., at a diameter of 32 mm. (full maturity), ×6—same specimen as figures 8 and 9 on plate 51.
F, *Gastrioceras clinei clinei* Miller and Owen, n. sp. and n. var., at a diameter of 53.5 mm. (late maturity), ×2½—same specimen as figures 4 and 5 on plate 51.

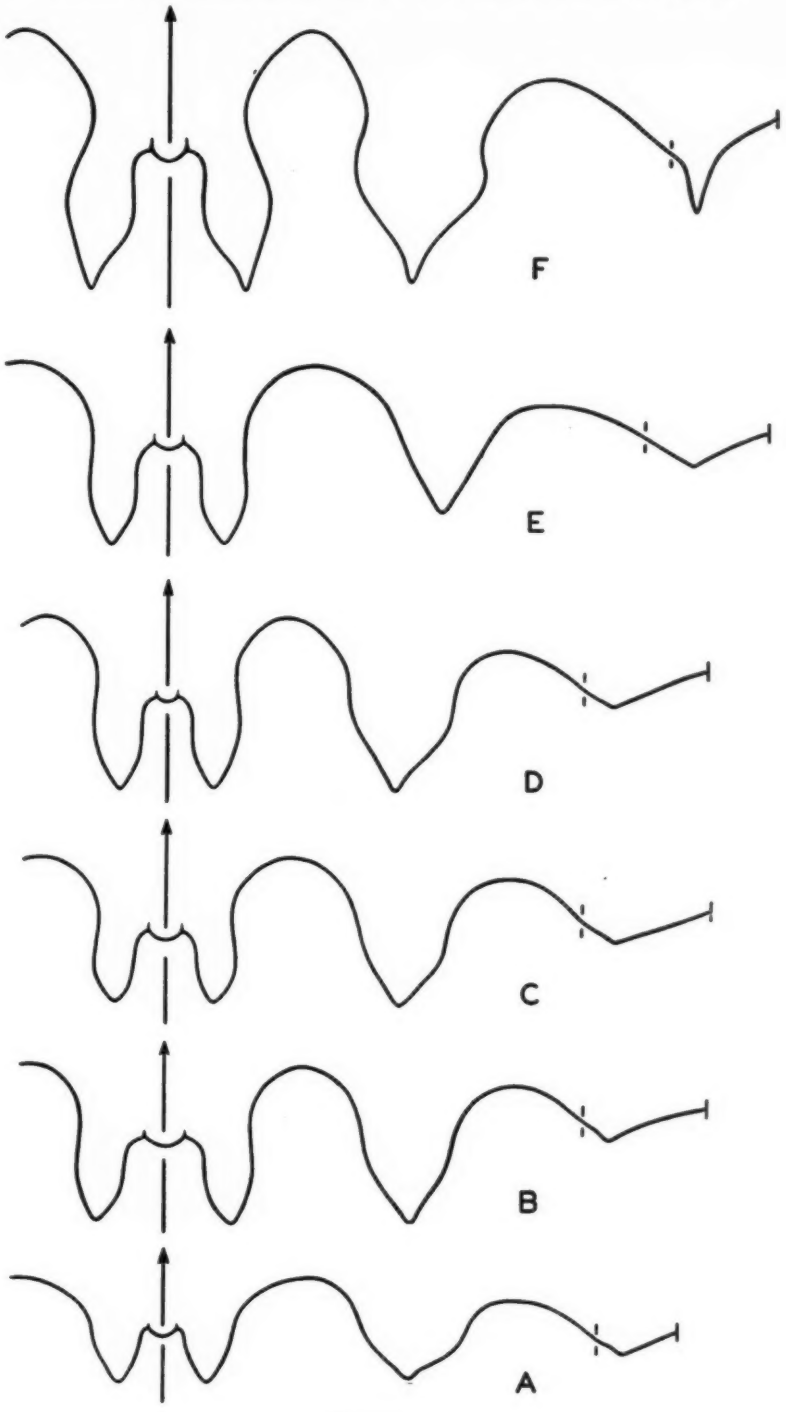

FIGURE 2

traces of fine longitudinal lirae are discernible on all portions of the conch—for the most part none of these lirae (even those on the umbilical shoulders) is evident on the internal mold. Growth lines somewhat variable and at maturity each is essentially straight and directly transverse or it forms a broad shallow rounded ventral sinus and on either side of it a low broad broadly rounded ventrolateral salient, a similar but smaller and more narrowly rounded lateral sinus, and a similar dorsolateral salient that centers on or near the umbilical shoulder. In some specimens the internal mold, at least, is marked by a few rounded sinuous constrictions which are in general parallel to the growth lines but are slightly less sinuous—the number and prominence of these contrictions vary on mature specimens, but they are always present and rather prominent during adolescence and early maturity. Length of camerae exceedingly variable and apparently of no taxonomic value. The early sutures develop as do those of typical representatives of *Gastrioceras*. At maturity each suture forms a large prominently subdivided ventral lobe and on either side of it a more or less U-shaped first lateral saddle, a V-shaped or tongue-shaped first lateral lobe, a broad asymmetrical relatively low second lateral saddle, a broad angular lobe (an umbilical lobe) on the umbilical wall, a low, broad, rounded internal second lateral saddle, a tongue-shaped internal first lateral lobe, and a rounded internal first lateral saddle which extends to the tongue-shaped dorsal lobe. The prongs of the ventral lobe are pointed and they are narrower than the saddle which divides them—that saddle is about half as high as the ventral lobe is deep, and it is divided medianly by a small rounded lobe. Siphuncle ventral and marginal.

Remarks: This species is by far the most abundant form in the fauna under consideration and we have more than 150 excellent representatives of it available for study. As might be expected, there is a considerable amount of variation among these specimens and we are somewhat uncertain as to whether or not all of them should be regarded as conspecific. However, all of the variations appear to be completely gradational, and therefore after giving the matter careful consideration we decided to place all of these specimens in the same species but to distinguish two varieties of that species. In typical forms, like that represented by figures 4 and 5 on plate 51, the umbilicus is relatively small and the sutures are rather advanced (text figs. 2D and 2F); whereas in other forms, like those represented by figures 6–9 on plate 51, the umbilicus is relatively large and the sutures are rather primitive (text figs. 2A and 2E). It should perhaps be noted in this connection that the sutures of small individuals of the first group (see text fig. 2D) are distinctly farther advanced than are those of larger individuals of the second group (see text fig. 2E). Since the first group is the typical one, its varietal name is the same as the specific name, and for the second group we propose the varietal name *warei*, in honor of Mr. John M. Ware, of Tulsa, Oklahoma, who first called our attention to the fauna. The figured specimens and those used in the compilation of the following table are not average specimens but rather are extremes—that is, the great majority of the specimens we are studying are more or less intermediate between these extremes and therefore they cannot be satisfactorily referred to either of the varieties we are distinguishing. In general, the forms we are referring to the variety *warei* have larger umbilici and more primitive sutures than do representatives of the typical variety—insofar as we have been able to ascertain, these two characters are the only ones that are of value in differentiating the two varieties, but the growth lines of *warei* seem to be less strongly sinuous than do those of *clinei*.

In order to elucidate the differences between the various species of *Gastrio-*

ceras that occur in the fauna we are studying, we have compiled the following table, which is self-explanatory.

Table 1—Comparison of the various species of Gastrioceras *in the Coffeyville formation near Collinsville, Oklahoma*

Species	Diameter of specimen (mm.)	Diameter of umbilicus compared to that of specimen (per cent)	Width of conch compared to diameter of specimen (per cent)	Sutures
Gastrioceras prone—holotype	11.0	69	42	primitive
Gastrioceras jonesi—fig. 10 on pl. 51	11.6	48	82	average
Gastrioceras jonesi	12.6	55	91	average
Gastrioceras jonesi—holotype	62.0	45	90	advanced
Gastrioceras retiferum—figs. 8–10 on pl. 52	10.3	40	85	average
Gastrioceras clinei warei	11.5	41	83	primitive
Gastrioceras clinei warei—figs. 6 and 7 on pl. 51	11.3	37	82	primitive
Gastrioceras clinei warei—holotype	36.1	50	60	average
Gastrioceras clinei warei	32.7	52	64	average
Gastrioceras clinei clinei—text fig. 2D	11.4	36	73	advanced
Gastrioceras clinei clinei	30.9	40	60	advanced
Gastrioceras clinei clinei—holotype	73.2	43	63	advanced

Occurrence: Abundant in concretions in Coffeyville formation (just above Dawon coal), about three-quarters of a mile south of Collinsville, Oklahoma.

Type specimens: The holotypes of *Gastrioceras clinei clinei* and *G. clinei warei* are both at the State University of Iowa, where they are numbered 1994 and 1993, respectively—unfigured paratypes at the same institution are numbered 1992. The rest of the figured type specimens (including those on which the text figures are based) are in the private collection of John Britts Owen, of Clinton, Missouri. The collections of the Kansas Geological Survey also contain representatives of this species.

GASTRIOCERAS JONESI Miller and Owen, n. sp.
Plate 51, figures 1–3, 10

Conch, which at full maturity consists of at least nine or ten volutions, is subglobular, ammoniticonic, and large. Holotype, which is septate throughout, attains a maximum diameter (measured across the umbilicus) of about 62 mm. and a maximum height and width of conch of about 25 mm. and 56. mm., respectively; and the collections we are studying contain a fragmentary septate specimen that is at least 25 percent wider. Whorls are helmet-shaped in cross section, being strongly depressed dorsoventrally (more than twice as wide as high), very broadly rounded ventrally and ventrolaterally, subangular laterally (at the umbilical shoulders), and impressed dorsally. Umbilicus deep and moderately large, but relatively it appears to become slightly smaller during late stages of ontogenetic development. The diameter of the umbilicus at full maturity is equal to about two-fifths that of the conch.

Test thin and essentially smooth except along umbilical shoulders, where it is somewhat thickened to form more or less of a low rounded inconspicuous ridge or keel. Internal mold of some specimens, at least, is marked by rounded sinuous transverse constrictions, of which there are three or four to the volution. These constrictions are particularly prominent on the early volutions of the conch and are much more prominent on the penultimate volution

of the holotype than on the ultimate volution—in no case do they extend dorsad of the umbilical shoulders. During early maturity each constriction forms a single broad rounded salient in its course from umbilical shoulder to umbilical shoulder, but at full maturity each appears to form slight ventral and ventrolateral sinuses. Traces of the increments of growth preserved on the internal mold of the conch are essentially parallel to the constrictions, and on the umbilical walls they are nearly straight but are very slightly convex apicad.

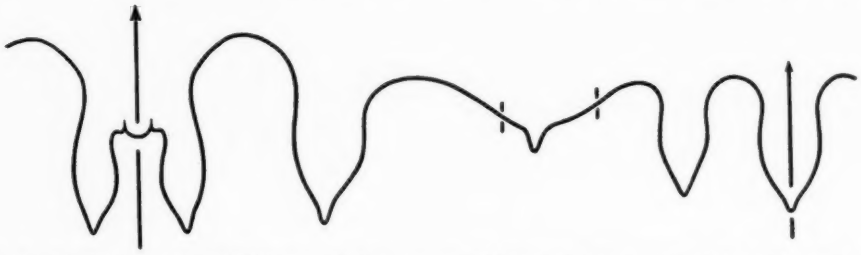

FIG. 3—*Gastrioceras jonesi* Miller and Owen, n. sp. Diagrammatic representation of one of the adoral sutures of the holotype (at a diameter of 52 mm.), ×1½. Same specimen as figures 1–3 on plate 51.

Length of camerae quite variable and apparently of no taxonomic value. At full maturity each suture forms a large prominently subdivided ventral lobe and on either side of it a high more or less U-shaped rounded first lateral saddle, a pointed tongue-shaped first lateral lobe, a broad relatively shallow asymmetrical rounded second lateral saddle, a broad acuminate lobe (an umbilical lobe) on the umbilical wall, an asymmetrical rounded internal second lateral saddle, a tongue-shaped internal first lateral lobe, and a rounded more or less U-shaped internal first lateral saddle, which extends to the tongue-shaped dorsal lobe (see text fig. 3). The prongs of the ventral lobe are asymmetrically tongue-shaped and are slightly narrower than the saddle between them. That saddle is about half as high as the ventral lobe is deep and it is divided medianly by a small rounded lobe. During early maturity the median saddle in the ventral lobe is relatively lower than at full maturity, the first lateral saddle and the first lateral lobe are relatively wider, and the lobe on the umbilical wall is less acuminate (text

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EXPLANATION OF PLATE 52

All specimens illustrated on this plate came from concretions in the Coffeyville formation, just above the Dawson coal, about three-quarters of a mile south of Collinsville, Oklahoma.

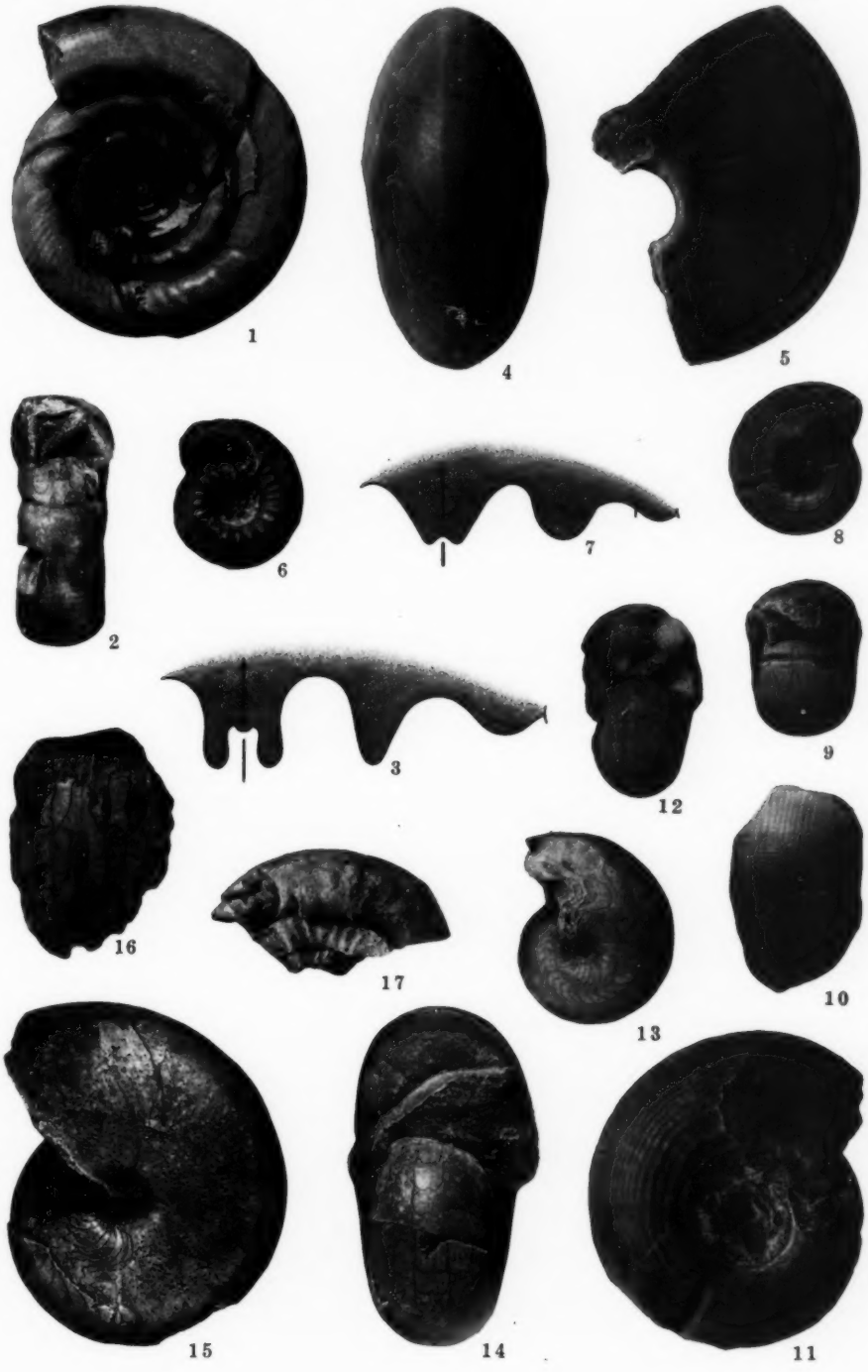
FIGS. *1–3—Gastrioceras prone* Miller and Owen, n. sp. Lateral and ventral views of the holotype, ×4 and 3 respectively; and diagrammatic representation of an adoral suture of same specimen, ×12½. (p. 415)

4–7—Eudissoceras collinsvillense Miller and Owen, n. sp. Two of the syntypes, ×4, and a diagrammatic representation of an external suture, ×10; *7*, which illustrates the shape of the sutures where the conch is about 5 mm. in diameter, is based on the penultimate volution of the specimen represented by *4* and *5*. (p. 409)

8–11—Gastrioceras retiferum Miller and Owen, n. sp. The two syntypes, ×2; *10* represents a fragment (ventrolateral portion of the conch) of an adoral volution of the specimen represented by *8* and *9*. (p. 416)

12–15—Prothalassoceras inexpectans Miller and Owen, n. sp. Two of the syntypes—*12* and *13* are ×2; *14* and *15* are ×1½. (p. 418)

16, 17—Schistoceras unicum Miller and Owen, n. sp. Ventral and lateral views of the holotype, ×2. (p. 420)



Miller and Owen, Pennsylvanian Cephalopods

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fig. 2C). Siphuncle small, ventral, and marginal.

Remarks: The above description is based largely on the holotype, but several large rather poorly preserved specimens and several small well-preserved specimens are available for study. This species, which is named in honor of Mr. D. J. Jones who collected the holotype, seems to be somewhat similar to *Gastrioceras excelsum* (Meek), the type specimen of which came from near Osage, Kansas, but the proportions of its conch are different, its umbilicus is relatively smaller, and there is no good reason to believe that its conch attains the large size characteristic of mature representatives of that species. The collections we are studying contain a few small specimens that seem to be more or less intermediate between this species and *Gastrioceras clinei*. For a tabular comparison of the characteristics of this species with those of congeneric forms that occur in association with it, see the table that is included with the discussion of *Gastrioceras clinei*.

Occurrence: Concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma.

Types: The holotype and several of the paratypes are at the State University of Iowa, where they are numbered 1900 (holotype) and 1989; the rest of the paratypes (including the one represented by figure 10 on plate 51) are in the private collection of John Britts Owen, of Clinton, Missouri.

GASTRIOCERAS PRONE Miller and Owen, n. sp.
Plate 52, figures 1–3

Conch subdiscoidal, ammoniticonic, and moderately small, attaining a maximum diameter (measured across the umbilicus) of at least 12 mm. and a maximum height and width of conch of at least 3 mm. and 5 mm., respectively. Whorls depressed dorsoventrally (about three-fifths as high as wide) and reniform in cross section, being very broadly rounded ventrally, rather narrowly rounded laterally, slightly impressed dorsally—both ventrolateral and dorsolateral zones of conch are rounded. Conch is very gradually expanded orad and it consists of at least seven volutions. Living chamber at least seven-eighths of a volution in length.

Umbilicus large and open, but imperforate; its diameter is equal to about two-thirds that of specimen. Umbilical shoulders rounded but fairly distinct.

Protoconch small. Test thin. Each volution of the conch (except the adapical one) is marked by about three rounded constrictions, which are rather prominent, and which appear to be oblique, as along the lateral zones of the conch they slope orad toward the venter and on the ventral side of the conch each forms a broad low broadly rounded salient. The growth lines, which are of the protractive type, are in general parallel to these constrictions, but they seem to be slightly less strongly sinuous and slightly less strongly oblique—also, they are somewhat curved on the lateral sides of the conch so that each forms a slight sinus there. Impressions of the constrictions and the increments of growth are very distinct on the internal mold, where, in addition, there is a rather indistinct low rounded small ridge or raised line along the venter.

Near the adapical end of the outer volution of the holotype, two camerae are exposed. These are moderate in length, and adjacent sutures do not come particularly close to each other at any point. Each of the adoral sutures of the holotype forms a moderately large almost straight-sided prominently subdivided ventral lobe (the prongs of which are U-shaped) and on either side of it a very slightly smaller U-shaped first lateral saddle, a smaller V-shaped but narrowly rounded first lateral lobe (which centers outside the umbilical shoulder on the broad ventral side of the conch), a rather low and broad asymmetrical rounded second lateral saddle (which centers on or near the umbilical shoulder), a rather low broad rounded

lobe (an umbilical lobe) on the umbilical wall, and apparently a small saddle on the umbilical seam—nature of internal sutures and siphuncle not determined, but presumably they do not differ greatly from those of other similar species.

Remarks: This species is not very similar to *Goniatites listeri* Phillips, the genotype of *Gastrioceras*, and it probably should not be placed in the same genus with it. Still, it is closer to that form than to any other valid genotype, and after giving the matter careful consideration we have concluded that for the present at least it will be best for us not to establish a new genus for it. That is, the forms that are now generally referred to *Gastrioceras* need to be divided into several genera (or subgenera), but we have not been able to work out a satisfactory basis for such a subdivision. Insofar as general shape of conch and growth lines and constrictions are concerned, our form resembles *Goniatites jossae* de Verneuil, the genotype (or subgenotype) of *Paragastrioceras* Tchernow [=*Girtyites* Wedekind], but the cross section of its conch is different, it does not bear lateral ribs (or nodes) or longitudinal lirae, and the ventral lobe of its sutures is much smaller and less prominently subdivided. In *Goniatites spirorbis* Phillips, the genotype of *Nomismoceras* Hyatt, the umbilicus is large, but the whorls are compressed rather than depressed and the ventral lobe of the sutures is not straight-sided or deeply notched. As a matter of fact, the species under consideration does not seem to be particularly close to any described species. For a tabular comparison of its characteristics with those of congeneric forms that occur in association with it, see the table that is included with the discussion of *Gastrioceras clinei*.

Occurrence: Concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma.

Holotype: Private collection of John Britts Owen, of Clinton, Missouri.

GASTRIOCERAS RETIFERUM Miller and Owen, n. sp.

Plate 52, figures 8–11

Conch subglobular, ammoniticonic, and moderately large, attaining a maximum diameter (measured across the umbilicus) of at least 23 mm. and a maximum height and width of conch of at least 8 mm. and 12 mm., respectively. Inner volutions of conch are more strongly depressed than outer ones, and until conch attains a diameter (measured across the umbilicus) of more than 10 mm., its whorls are less than half as high as wide—at the adoral end of the larger of the syntypes, conch is about two-thirds as high as wide. Umbilicus moderately large, and apparently it becomes relatively larger during later stages of ontogenetic development. On the outer volution of the larger of the syntypes, the diameter of the umbilicus is equal to almost one-half that of the specimen. Umbilical shoulders abruptly rounded and, on internal mold, at least, slightly but distinctly crenulate.

Surface of conch (but not umbilical walls) marked by some forty to forty-five prominent subangular longitudinal lirae, subdued replicas of which are preserved on the internal mold. Small fragments of the test that adhere to the smaller of the syntypes show that at least the rounded grooves between the lirae are crossed by small transverse raised lines, giving the surface of the conch a reticulate appearance—on a fragment of an adoral volution of the same specimen distinct traces of these transverse lines are preserved on the internal mold (see figure 10 on plate 52). Also, internal mold at least is marked by prominent transverse rounded constrictions, of which there are about two to the volution. These constrictions, which do not extend across the umbilical walls, are very slightly sinuous, forming very shallow ventral and lateral sinuses. Traces of the increments of growth preserved on the internal mold are essentially parallel to

the constrictions—these traces ar rathere prominent on the dorsolateral portions of the conch, causing the umbilical shoulders to be crenulate, but they are relatively faint on the ventral side of the conch.

Each external suture (see text figure 2B) consists of a large straight-sided rather prominently subdivided ventral lobe, and on either side of it a slightly asymmetrical U-shaped first lateral saddle, a rather large more or less V-shaped acuminate first lateral lobe, a relatively broad low rounded asymmetrical second lateral saddle, and a low pointed asymmetrical lobe on the umbilical wall centering just inside the umbilical shoulder. The prongs of the ventral lobe are tongue-shaped, and are considerably narrower than the intervening saddle, which is U-shaped, and divided medianly by a small rounded lobe.

Remarks: Insofar as we have been able to ascertain, the large open umbilicus and the prominent surface ornamentation of the test are sufficient to distinguish this species from all described forms. Specific comparisons, therefore, seem unnecessary. For a tabular comparison of the characteristics of this species with those of congeneric forms that occur in association with it, see the table that is included with the discussion of *Gastrioceras clinei*.

Occurrence: Concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma, where it is rather rare.

Syntypes: The specimen represented by figures 8–10 on plate 52 is in the private collection of John Britts Owen, of Clinton, Missouri; the other syntype, which is represented by figure 11 on plate 52, is at the State University of Iowa, where it is numbered 1997.

Genus BISATOCERAS Miller and Owen, n. gen.

The collections we are studying contain several representatives of a species that does not seem to be referable to any described genus, and we propose to establish for it a new genus, *Bisatoceras*, named in honor of Mr. W. S. Bisat, who has added so much to our knowledge of British Carboniferous goniatites.

The new genus (genotype, *B. primum*) can be diagnosed as follows: Conch subdiscoidal and ammoniticonic. Umbilicus closed. Growth lines form ventral and lateral sinuses and ventrolateral and dorsolateral salients. Each mature suture forms a broad, straight-sided, very prominently subdivided ventral lobe and on either side of it a U-shaped first lateral saddle, a pointed first lateral lobe, a low, broad, rounded second lateral saddle, a small lobe near the umbilical seam, a low, broad, rounded internal second lateral saddle, a pointed internal first lateral lobe, and a rounded internal first lateral saddle, which extends to the tongue-shaped dorsal lobe—the secondary saddle in the ventral lobe is almost as high as the lobe is deep and it is divided medianly by a small subangular lobe. Siphuncle ventral and marginal in position.

The most distinctive characters of this species are the form of its sutures (particularly the ventral portions), the shape of the growth lines, and the closed umbilicus. In most of the Carboniferous goniatites in which each mature suture forms a total of eight primary lobes, the umbilicus is not closed, and in the few that have closed umbilici, for example *Milleroceras*, *Goniolobоceras*, etc., the ventral lobe of the sutures is not at all like that of the form under consideration.

The paleontological collections of the State University of Iowa contain numerous representatives of an undescribed species of this genus from the lower Pennsylvanian (Wewoka?) of Oklahoma.

BISATOCERAS PRIMUM Miller and Owen, n. sp.
Plate 50, figures 6–14

Conch ammoniticonic, subdiscoidal at maturity, and moderately large, attain-

ing a maximum diameter (measured across the umbilicus) of at least 34 mm. and a maximum height of at least 20 mm. Inner volutions of conch are depressed dorsoventrally, and therefore during adolescence conch is subglobular in shape. However, throughout ontogenetic development, height of conch increases more rapidly than width, and by the time conch has attained a diameter (measured across the umbilicus) of some 12½ mm., it is about as high as wide; at full maturity it is distinctly higher than wide and is subdiscoidal in shape. Umbilicus small and closed. Umbilical shoulders low, rounded, and inconspicuous. Living chamber at least one volution in length. Test very thin and its inner surface or layer ("Runzelschicht") is very finely papillose.

Early volutions of conch bear rounded transverse constrictions, which are very prominent and are particularly deep on the lateral zones of the conch. These constrictions are slightly sinuous, and they form slight ventral and lateral sinuses and similar ventrolateral and dorsolateral salients. As full maturity is attained the constrictions disappear. The adapical volutions of the conch are also marked by rather prominent growth lines, which are essentially parallel to the constrictions. On the mature portion of the conch the growth lines, though in general similar to those of adolescence, are much more strongly sinuous, and each forms a moderately deep rounded ventral sinus and on either side of it a rather prominent rounded ventrolateral salient, a relatively broad and shallow rounded lateral sinus, and a similar dorsolateral salient.

At maturity each suture forms a broad, very prominently subdivided ventral lobe and on either side of it a narrow asymmetrical, more or less U-shaped first lateral saddle, a rather large broad acuminate first lateral lobe, a relatively low, broad, broadly rounded second lateral saddle, a broad, shallow rounded lobe centering just outside the umbilical seam, a low, broad, broadly rounded asymmetrical internal second lateral saddle, a relatively deep pointed internal first lateral lobe, and a rounded more or less U-shaped internal first lateral saddle, which extends to the moderately large pointed tongue-shaped dorsal lobe. During adolescence the median secondary saddle in the ventral lobe is relatively low, and the sides of the ventral lobe converge apicad (see figure 12 on plate 50), but at full maturity the sides of the ventral lobe are nearly parallel, and the median secondary saddle in the ventral lobe is almost as high as the lobe is deep, and, as before, is divided medianly by a small subangular lobe (see figure 14 on plate 50)—also the first lateral saddle becomes relatively narrower during ontogenetic development. Siphuncle small, circular in cross section, and ventral and marginal in position.

Remarks: Since this species is the first representative of the genus to be described, specific comparisons seem unnecessary. Its most distinctive characters are its closed umbilicus, its biconvex growth lines, and its gastrioceran sutures in which the ventral lobe is straight-sided and is divided medianly by a secondary saddle that is almost as high as the lobe is deep.

Occurrence: Concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma, where it is rather rare.

Syntypes: The four specimens represented by figures 6–14 on plate 50 and five unfigured specimens are in the private collection of John Britts Owen, of Clinton, Missouri; and the collections of the State University of Iowa contain four unfigured syntypes numbered 1998.

PROTHALASSOCERAS INEXPECTANS
Miller and Owen, n. sp.

Plate 52, figures 12–15

With the exception of *Gastrioceras clinei*, the most abundant species in the fauna under consideration is an undescribed representative of *Prothalasso-*

ceras. Until recently that genus was thought to be characteristic of the Permian, and, as we did not expect to find it occurring in beds as old as the Coffeyville formation, we are calling our form *Prothalassoceras inexpectans*. It is a primitive representative of the genus, and the details of the digitation of the lobes of the sutures do not seem to have become stabilized.

Conch subglobular, ammoniticonic, and moderately large, attaining a maximum diameter (measured across the umbilicus) of as much as 42 mm., and a maximum height and width of conch of at least 20 mm. Early volutions of conch are considerably wider than high, but throughout ontogenetic development dorsoventral diameter of conch increases more rapidly than lateral diameter and in adoral portion of large specimens height and width of conch are about equal. Umbilicus small and closed, or nearly so—at full maturity its diameter is equal to slightly less than one-fourth that of specimen. Umbilical shoulders low and rounded but fairly distinct. Living chamber at least four-fifths of a volution in extent.

Test thin and its inner surface or layer ("Runzelschicht") is finely papillose. During adolescence the papillae are rounded, but as maturity is reached they become more or less elongate or "wrinkle-like." Outer surface of test is marked by only the growth lines. At maturity each growth line forms a moderately deep rounded ventral sinus and on either side of it a relatively low rounded ventrolateral salient, a shallow broadly rounded lateral sinus, and a small but rather prominent rounded dorsolateral salient, which centers on (or just outside) the umbilical shoulder.

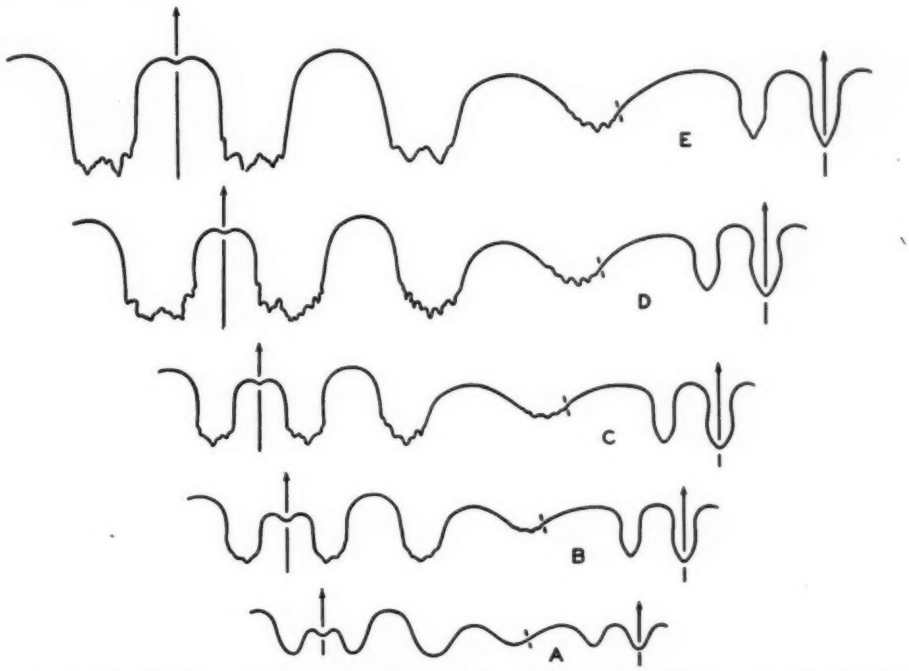

FIG. 4—*Prothalassoceras inexpectans* Miller and Owen, n. sp. Diagrammatic representations of sutures at diameters of *A* 1.8 mm., ×16½; *B* 4.2 mm., ×10; *C* 8.7 mm., ×7; *D* 15 mm., ×4; and *E* 21 mm., ×3½. *E* is based on the specimen represented by figures 14 and 15 on plate 52.

The earliest sutures develop essentially as do those of *Gastrioceras*, and during early adolescence the sutures pass through a so-called *Gastrioceras* stage of development (see text figure 4A). Following this, all of the lobes of the external sutures become digitate; the median saddle in the ventral lobe becomes U-shaped and almost as high as the lobe is deep; the median subdivision (lobe) of the ventral lobe becomes very small and inconspicuous; and the lobes of the internal sutures become tongue-shaped. The precise nature of the digitation of the lobes of the external sutures of several specimens of varying diameter is well shown by text figure 4, but it should perhaps be pointed out that the details of this digitation vary from specimen to specimen and even on the two sides of the same specimen (compare the digitation of the two main prongs of the ventral lobe in text figures 4D and 4E). Siphuncle small, circular in cross section, and ventral and marginal in position.

Remarks: This species can be distinguished from all described congeneric forms by means of the relative height of the median saddle in the ventral lobe of its mature sutures, and by means of the details of the digitation of the lobes of its external sutures. In *P. welleri* Böse of the Leonard formation of western Texas, *P. keytei* Smith and *P. kingorum* Miller of the Gaptank formation of western Texas, *P. gemmellaroi* (Karpinsky) of the Artinsk sandstone of the southern Urals, *P. karpinskyi* (Toumansky) of the Mount Kichkhi-Burnu (Marta River) beds of Crimea, and *P.? microdiscus* (Gemmellaro) of the Sosio beds of Sicily and possibly the Trogkofel limestone of the Carnic Alps the median saddle in the ventral lobe is considerably lower than the lobe is deep, and in *P. dieneri* (Smith) of the Bitauni beds of Timor it is relatively longer than in the form under consideration.

The shape of the sutures of *Prothalassoceras* during ontogenetic development has not been recorded previously, but in 1934 Voinova (3) published a discussion and illustrations of the development of the sutures in a typical representative of *Thalassoceras*. In that genus the number of digits on the lobes of the external sutures is increased progressively throughout ontogenetic development, whereas in the form under consideration the number of digits remains fairly constant, though the size of the digits is, of course, increased.

Occurrence: Abundant in concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma.

Syntypes: Both of the syntypes represented by figures 12–15 on plate 52 are at the State University of Iowa, where they are numbered 1996—other syntypes in the same collection are numbered 1995. The eight specimens on which text figures 4A–4D are based (and numerous other syntypes) are in the private collection of John Britts Owen, of Clinton, Missouri. Also, the collections of the Kansas Geological Survey contain a representative of this species.

SCHISTOCERAS UNICUM Miller and Owen, n. sp.
Plate 52, figures 16, 17

We have one small specimen from the concretions in the Coffeyville formation that is referable to the genus *Schistoceras*. It is rather fragmentary and incomplete to serve as the type of a new species, but it is fairly well preserved and is so different from all described species that conspecific forms, when found, can be recognized readily.

Holotype is an internal mold of part of three volutions of the phragmacone of a subglobose ammoniticonic conch, which attained a maximum diameter (measured across the umbilicus) of at least 15 mm. and a maximum height and width of conch of at least 6 mm. and 11½ mm., respectively. Whorls strongly depressed dorsoventrally (almost twice as wide as high) and reniform in cross section, being very broadly rounded ventrally, more narrowly rounded laterally, and slightly

impressed dorsally—both ventrolateral and dorsolateral zones are rounded. Umbilicus large and open—its diameter is equal to about two-thirds (estimated) that of specimen. Umbilical shoulders rounded and indistinct. Umbilical walls broadly rounded.

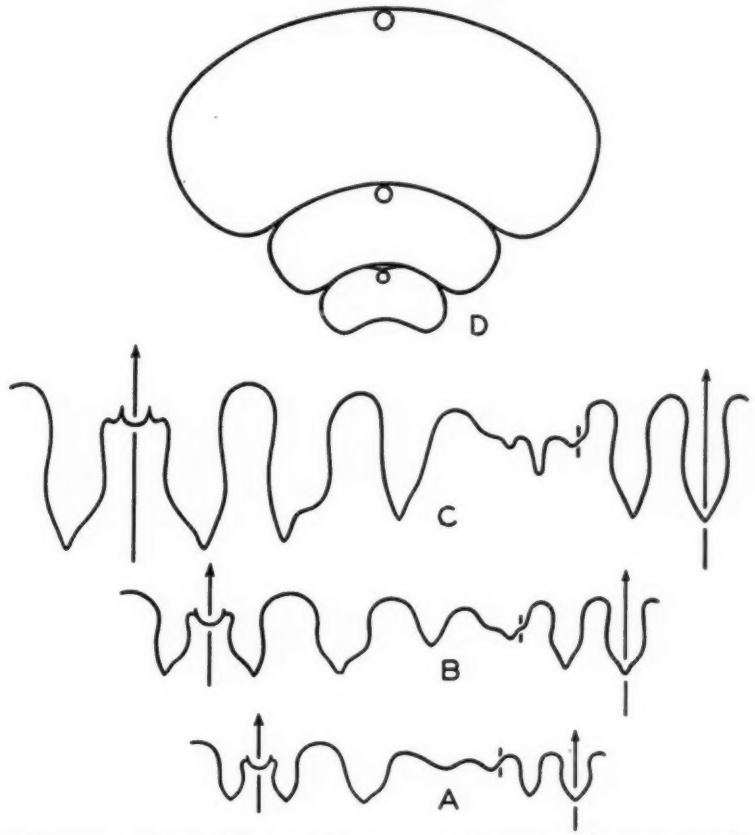

FIG. 5—*Schistoceras unicum* Miller and Owen, n. sp. Diagrammatic representations of the sutures of each of the three volutions of the conch represented by the holotype, and a diagrammatic cross section of the holotype. *A* is ×10; *B* is ×7½; *C* and *D* are ×5.

Lateral zones of conch marked by small but rather prominent rounded ribs, which are directly transverse to the long axis of the conch—it is estimated that there are some thirty-five of these ribs to the volution. Each growth line forms along the venter a small moderately shallow rather broadly rounded hyponomic sinus, and on either side of it (on the broad ventral side of the conch) a similar but slightly larger and slightly asymmetrical salient, the outer (dorsad) portion of which swings rather strongly apicad and is distinctly recurved on the ventrolateral zones of the conch, where a pair of growth lines seems to more or less grade into a lateral rib—faint traces of the increments of growth are discernible on the internal mold.

On the innermost of the three volutions of the holotype each suture forms a large prominently subdivided ventral lobe, and on each side of it a large slightly asymmetrical U-shaped first lateral saddle, a large slightly asym-

metrical V-shaped first lateral lobe, a low asymmetrical rounded second lateral saddle, a shallow broadly rounded second lateral lobe, a similar third lateral saddle, a similar but more narrowly rounded third lateral lobe (an umbilical lobe), a higher asymmetrical rounded internal second lateral saddle (which centers just inside the umbilical seam), a much deeper V-shaped internal first lateral lobe, and a slightly larger more or less U-shaped internal first lateral saddle which extends to the rather large pointed tongue-shaped dorsal lobe (see text figure 5A). Throughout ontogenetic development all of these lobes and saddles become more prominent and most of them become relatively narrower. Also, on the second volution of the holotype the second lateral saddle of the external suture is U-shaped, the adjacent second lateral lobe is V-shaped, and the umbilical lobe is incipiently trifid. Then, on the outermost volution of the holotype the umbilical lobe is divided into three small narrowly rounded unequal lobes, all of which center outside the umbilical seam (see text figure 5C), and it almost appears as though the outer two of these three (which are much shallower than the median one) are starting to become bifid.

Siphuncle small, circular in cross section, and ventral and marginal in position. On outer volution of holotype, siphuncle is only a little more than one-half mm. in diameter.

Remarks: On the innermost volution of the holotype of this species there is a rather prominent groove along the venter (see figure 5D). However, this groove is not quite median in position and we believe that it is most probably adventitious—the groove seems to have been filled with shell material, for no trace of it is discernible on the adjacent part (impressed zone) of the following volution.

With the possible exception of *Schistoceras fultonense* (Miller and Gurley) and *S. hildredthi* (Morton), of which the exact stratigraphic horizons are not ascertainable, the above-described species is the oldest known representative of the genus *Schistoceras*, and its large umbilicus, low whorls, lateral ribs, and peculiar sutures (with three small lobes just outside the umbilical seam) serve to distinguish it from all congeneric forms. It is not closely similar to any other known form, and if the adoral end of the holotype represents a mature portion of the phragmacone, this species is probably the most primitive representative of the genus *Schistoceras* known.

Occurrence: Concretions in Coffeyville formation (just above Dawson coal), about three-quarters of a mile south of Collinsville, Oklahoma.

Holotype: Private collection of John Britts Owen, of Clinton, Missouri.

REFERENCES

1. Ohern, D. W., The stratigraphy of the older Pennsylvanian rocks of northeastern Oklahoma: *Oklahoma State Univ., Research Bull.* 4, p. 23, 1910.
2. ——— in Green, F. C., A contribution to the geology of eastern Osage County [Oklahoma]: *Am. Assoc. Petroleum Geologists Bull.*, vol. 2, p. 122, 1918. (Also, unpublished manuscript on the geology of the Nowata and Vinita quadrangles, Oklahoma.)
3. Voinova, E., Some ammonites from the Baigendja horizon of the Artinskian, South Ural: *United Geol. Prosp. Service U.S.S.R., Trans.*, fasc. 352, pp. 38–40, 55–56, 1934.

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THE LOWER MIDDLE DEVONIAN TETRACORALS OF THE NEVADA LIMESTONE[1]

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ABSTRACT

The Tetracoral fauna of the basal 500 feet of the Nevada limestone is described. The fossils are classified under 13 genera, of which *Nevadaphyllum*, *Eurekaphyllum*, *Papiliophyllum*, and *Radiastraea* are new. *Billingsastraea* Grabau is erected to full generic standing. Twenty-one new species and one new variety are proposed.

Although a great deal of systematic study has been devoted to the Devonian coral faunas of eastern and central North America, almost no attention has been given to those of the Cordilleran region. With the exception of a few species described by Meek, Lambe, and Billings from the MacKenzie District of northwest Canada; by Meek from the White Pine District in east-central Nevada; by Stauffer from the Inyo Mountains in southeastern California; and a few specimens referred to eastern forms by Walcott from the Eureka district in east-central Nevada, the Devonian coral faunas of the Cordilleran region are relatively unknown.

The first descriptions of fossils from the Nevada limestone were made in 1877 by F. B. Meek (1), who described a number of species from various horizons and localities, including a few corals from Upper Devonian sections in the White Pine Mountains. C. D. Walcott in 1884 (2) referred several species of corals from the Nevada limestone to forms occurring in Devonian strata in eastern and central North America, and noted the occurrence of several new species from both the Middle and Upper Devonian horizons. In 1928 Edwin Kirk made extensive collections of fossils from numerous horizons throughout both the Middle and Upper Devonian parts of the Nevada limestone at several localities in east-central Nevada. In 1934 and 1935, Charles W. Merriam, of Cornell University, in the course of revising the Middle Paleozoic stratigraphy of east-central Nevada, also made collections of fossils from the Nevada limestone.

The present work, based chiefly on Kirk's collections from east-central Nevada, was begun at the United States National Museum in 1932, at the suggestion of Doctor Kirk, to whom I am indebted for invaluable advice on the stratigraphy, and was completed at Princeton University during the academic years 1934–35 and 1935–36.

[1] This paper is a portion of a dissertation which was presented to the Department of Geology of Princeton University in May, 1936, as a partial fulfillment of the requirements for the degree of Doctor of Philosophy.

I am greatly indebted to Dr. Stanley Smith, of the University of Bristol, for his advice with regard to the very involved nomenclature of the Paleozoic corals. For some years Doctor Smith, in coöperation with Doctor W. D. Lang, of the British Museum, has been engaged in the investigation of the genotypes of the Paleozoic corals and the publication of revised generic diagnoses based on study of thin sections. This work has resulted in the clearing up of many of the involved and perplexing synonymies that have hampered the study of the Paleozoic corals in recent years. Doctor Smith has very kindly forwarded to me several revised generic diagnoses from his unpublished manuscripts. These have been of great value in the systematic classification of the Nevada limestone corals.

My thanks are also due to Doctor Merriam for the loan of corals from his collections from the Devonian of the Eureka district and for his advice on the stratigraphy of the Nevada formation.

The Nevada limestone crops out in east-central Nevada, mainly between latitude 39° and 40° and longitude 115°30′ and 116°30′. Most of the collections that have been made from this formation came from the regions surrounding the Eureka and the White Pine mining districts, where the most complete Devonian sections in the Cordilleran region are exposed. These sections comprise a series of more than 4,500 feet of Middle and Upper Devonian limestones.

The formation is a thick series of calcareous sediments with occasional small intercalated shaly or sandy beds. The formation rests conformably upon the Lone Mountain dolomite, the upper part of which is generally regarded as being of Middle Silurian age. The formation is overlain by the White Pine shale of Mississippian age.

The Nevada limestone has been broken into a series of massive blocks by the extensive post-Paleozoic faulting in the region, and there is no one locality in which the entire formation is exposed from base to summit. The complete Middle Devonian sequence, from the basal contact with the Lone Mountain dolomite to the *Stringocephalus* horizon, which is at the 2,340-foot level, is exposed at Lone Mountain, 18 miles northwest of Eureka, Nevada. Most of the Middle Devonian corals described in this paper were collected from this section.

The basal 500 feet of this section consists of a series of grey and brown argillaceous limestones. These strata contain a large and varied tetracoral fauna together with several species of tabulate corals of the genera *Favosites*, *Cladopora*, *Syringopora*, and *Aulopora*. Between the 500- and the 1,500-foot levels the lithology changes to a light-grey, finely crystalline limestone, containing at various levels silicified coral reefs composed mainly of large heads of *Prismatophyllum*, *Spongophyllum*, *Favosites*, and *Cladopora*. Between the 1,500-foot level and the *Stringocephalus* horizon the lithology changes to a dark-bluish, fine-grained limestone. At the 1,600-

foot level occurs a zone in which several species of the brachiopod genus *Martinia*, including the species *M. maia* and *M. undifera*, are found. In the region of the 2,200-foot level is a coral fauna including heads of *Prismatophyllum* and *Heliolites* associated with the brachiopod *Atrypa missouriensis*.

Other sections of the Middle Devonian sequence from which collections of corals have been made occur at Combs Mountain, Atrypa Peak, Lamoureux Canyon, Gray's Canyon, Modoc Peak, Brush Peak, Newark Mountain, and County Peak, in the Eureka district; at Romano, in the Sulphur Springs Mountains (Pinon Range of the 40th Parallel Survey); and at Frazier Creek, in the Roberts Mountains.

Between the *Stringocephalus* horizon and the beds containing typical Upper Devonian fossils there is about 2,000 feet of beds whose fauna is little known because of the lack of outcrops in the regions heretofore studied.

The upper 500 feet of the Nevada limestone is exposed at Devils Gate and at Yahoo Canyon, in the Eureka district, and at Treasure Peak and Babylon Hill, in the White Pine district. It contains such typical Upper Devonian tetracorals as *"Pachyphyllum" woodmani*, *Phillipsastraea verrilli*, *Phillipsastraea* aff. *hennahi*, and species of *MacGeea* and *Charactophyllum*, together with species of the tabulate coral genera *Favosites*, *Alveolites*, *Cladopora*, and *Syringopora* in association with the brachiopods *Hypothyridina emmonsi*, *Cyrtospirifer whitneyi*, and *Pugnax pugnus*.

It is to be expected that the Nevada limestone will be subdivided into smaller stratigraphic units on the basis of its diverse faunas, but more information regarding the faunal content of the 2,000 feet of the formation above the *Stringocephalus* horizon will be required before any accurate subdivisions can be made.

This paper deals with the description and systematic classification of the tetracorals occurring within the basal 500 feet of the Nevada limestone. This basal part of the formation was called Lower Devonian by Walcott in his monograph on the Paleontology of the Eureka district in 1884. Except the coral fauna the most characteristic fossils of these beds are *Spirifer pinonensis*, *Spirifer raricosta*, *Spirifer varicosa*, *Pterinea flabella*, *Actinopteria boydi*, *Cypricardinia indenta*, *Platyceras nodosum*, and *Dalmanites meeki*. This faunal assemblage suggests that this part of the formation is of Onondaga age. Many of the corals, however, are quite unlike those characteristic of the Onondaga limestone and find their closest relatives among those occurring within the lower Middle Devonian Calceola limestone of the Rhine Valley.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA
Class ANTHOZOA
Subclass TETRACORALLA
Family ZAPHRENTIDAE
Milne-Edwards and Haime, 1850

Genus HETEROPHRENTIS
Billings, 1874 (3)

Genotype: By original designation *Zaphrentis spatiosa* Billings 1858 (4) = *Zaphrentis prolifica* Billings 1858 (4) by subsequent designation of O'Connell 1914 (5).

HETEROPHRENTIS NEVADENSIS
Stumm, n. sp.
Plate 53, figure 1; plate 54, figure 1

External features: The holotype is a simple ceratoid coral with the proximal and distal ends removed by weathering. The specimen measures 3 cm. in length, and expands from a diameter of 1.7 cm. at the base to 2 cm. at the distal extremity. Weathering of the exterior has removed the epitheca and has exposed the peripheral ends of the septa. Pronounced growth expansions which increase the diameter of the specimen by as much as 4 mm. are present. These annulations are separated by an average distance of 7 mm.

Internal features: As seen in the transverse section, there are about 84 septa present. Weathering of the exterior of the holotype has removed the peripheral terminations of the septa except in the left cardinal and right counter quadrants, where it can be seen that the septa dilate at their peripheral ends to form an incomplete stereozone. The major septa extend to the axial region and the alternate minor septa are usually one-third as long. At various growth stages the major septa become twisted at their axial ends. All the septa are smooth and gently tapering toward their axial ends. A fossula is produced by the suppression of the cardinal septum, which extends only 2 mm. from the periphery. The minor septa on each side of the aborted cardinal septum bend around it and fuse at their axial ends. The tabulae are complete and usually distally convex, bending abruptly downward at their peripheral ends. They average slightly over 1 cm. in length, and are separated by distances ranging from 1 to 3 mm.

Remarks: The great majority of the corals with the general type of structure

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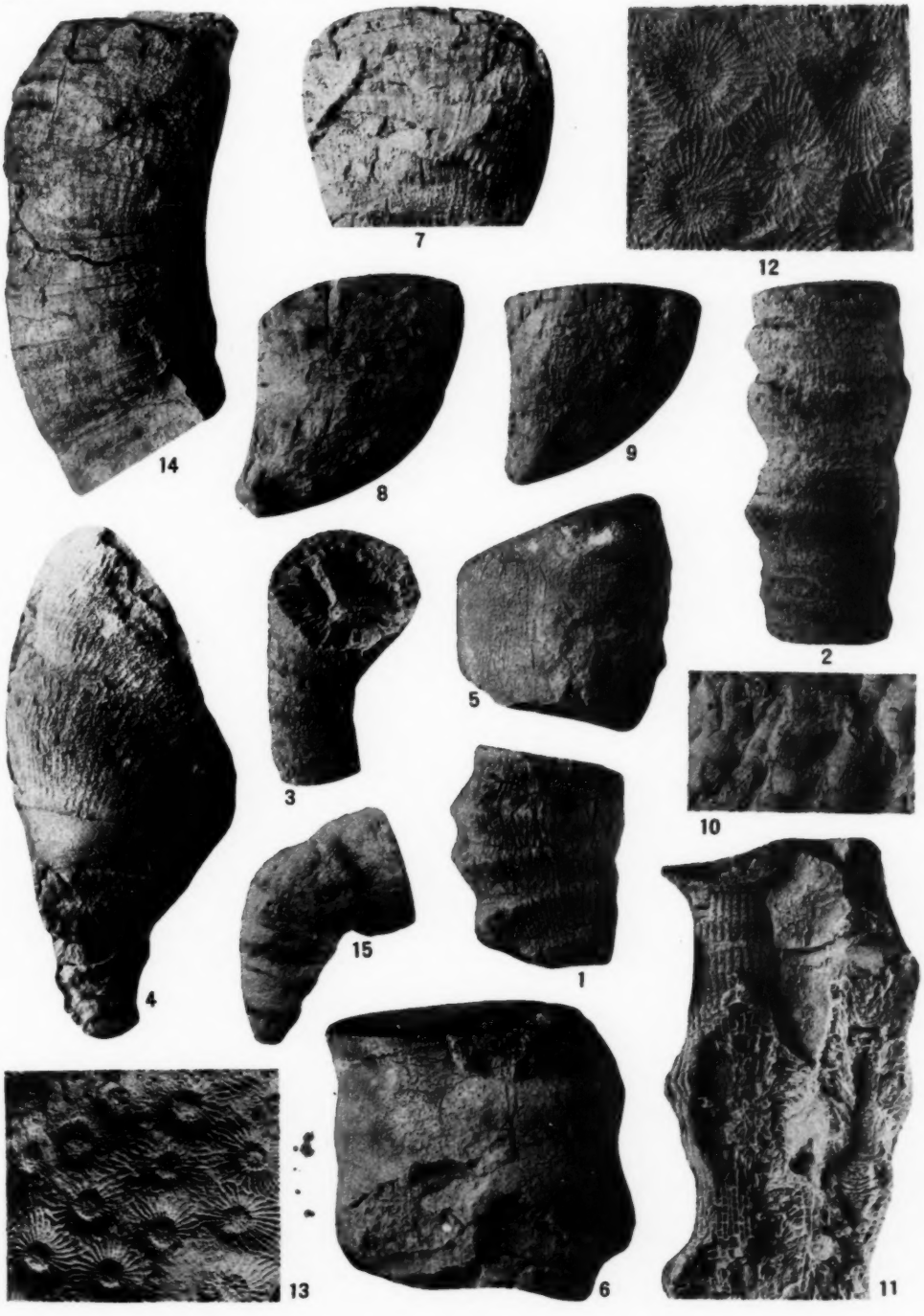
EXPLANATION OF PLATE 53

All figures natural size

FIG. *1*—*Heterophrentis nevadensis* Stumm, n. sp., side view of holotype. (p. 426)
2—*Amplexus invaginatus* Stumm, n. sp., side view of holotype. (p. 427)
3—*Amplexus nevadensis* Stumm, n. sp., view of holotype, showing septal structure and one of the tabulae. (p. 427)
4—*Amplexus lonensis* Stumm, n. sp., side view of holotype. (p. 428)
5—*Amplexus magnus* Stumm, n. sp., side view of holotype. (p. 428)
6—*Nevadaphyllum masoni* Stumm, n. sp., side view of holotype. (p. 429)
7—*Papiliophyllum elegantulum* Stumm, n. sp., view of cardinal side of holotype, showing vertical striations. (p. 430)
8—*Eurekaphyllum breviseptatum* Stumm, n. sp., side view of holotype. (p. 431)
9—*Grypophyllum nevadense* Stumm, n. sp., side view of holotype. (p. 432)
10—*Spongophyllum nevadense* Stumm, n. sp., view of a portion of corallum, showing the curved cylindroid corallites. (p. 435)
11—*Spongophyllum expansum* Stumm, n. sp., side view of a portion of holotype. (p. 436)
12—*Billingsastraea billingsi nevadensis* Stumm, n. var., view of a portion of weathered distal face of holotype. (p. 438)
13—*Radiastraea arachne* Stumm, n. sp., a portion of distal face of holotype. (p. 439)
14—*Mesophyllum robertsense* Stumm, n. sp., side view of holotype. (p. 440)
15—*Mesophyllum lonense* Stumm, n. sp., side view of holotype. (p. 440)



Stumm, Devonian Tetracorals

UNIV. OF MICH.

exhibited by *Heterophrentis nevadense* have been assigned to the genus *Zaphrentis* by most authors. As O'Connell (op. cit.) has shown, the genotype of *Zaphrentis* is *Z. phrygia* Rafinesque and Clifford = *Caryophyllia cornicula* Leseur (*Heliophyllum corniculum* auctt.), a small ceratoid coral, with carinate septa and a pronounced fossula. The great majority of the species assigned to this genus by subsequent authors do not have the carinate septa which characterize the genotype. Billings (op. cit.) created the genus *Heterophrentis* to distinguish those corals having a Zaphrentoid structure with the distinction that the septa are not carinate. In the author's opinion the smooth septate corals heretofore assigned to *Zaphrentis* can be placed more accurately in *Heterophrentis*.

Horizon and locality: Basal 500 feet of Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94442.

Paratype: U. S. Nat. Mus., 94442*a*.

Genus AMPLEXUS Sowerby 1814 (6)

Genotype: By monotypy, *Amplexus coralloides* Sowerby, op. cit.

AMPLEXUS INVAGINATUS
Stumm, n. sp.
Plate 53, figure 2; plate 54, figure 2

External features: The holotype is a simple cylindroid coral measuring 5.5 cm. in length and averaging 1.5 cm. in diameter. Both the proximal and distal terminations are missing. The exterior is vertically striated and possesses a very pronounced series of horizontal expansions, separated by distances ranging from 3 mm. to 1 cm., which appear to be the rims of former calyces through which the coral has continued growth by calycinal rejuvenescence.

Internal features: There are about 90 short, thin septa which extend less than half the distance to the axis but are still distinguishable into a major and minor series. The minor septa average two-thirds the length of the major. All the septa are dilated at the periphery to form a narrow stereozone from 1 to 2 mm. in width. Dissepiments are few and mainly confined to the peripheral zone where the minor septa are present. At certain growth stages the major septa in one or two quadrants become extended axially, producing a Zaphrentoid appearance. There is a well marked fossula formed by the reduction of the cardinal septum. The tabulae are complete and horizontal, occupying almost the entire diameter of the coral. They average 1 cm. in length and are separated by distances ranging from 0.5 to 1.5 mm. Along either peripheral extremity is a narrow zone averaging 2.5 mm. in diameter, which is occupied by an indistinct row of large, axially or peripherally convex dissepiments.

Remarks: The cylindroid form and the periodic invaginations as exhibited by this species are quite characteristic of the majority of the forms of *Amplexus*. These characters are present in *A. yandelli* of the Onondaga and *A. hamiltonae* of the Hamilton. *A. invaginatus* is distinguished from these forms by its greater size and larger number of septa, as well as by the presence of interseptal dissepiments and a peripheral stereozone.

Horizon and locality: Basal 500 feet of the Nevada limestone a little to the southeast of the highest point of Atrypa Peak, 7 miles southwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94443.

Paratype: U. S. Nat. Mus., 94443*a*.

AMPLEXUS NEVADENSIS
Stumm, n. sp.
Plate 53, figure 3; plate 54, figure 3

External features: The holotype is a cylindro-ceratoid coral with both the proximal and distal terminations missing. The specimen is 4 cm. in length, 1 cm. in diameter at the base, and 2 cm. in diameter at the top. For three-fourths of the distance from the base the specimen has a cylindroid form, then expands rapidly so that within a distance of 5

mm. it has doubled its diameter, producing a funnel-shaped appearance. The coral has been silicified, and removal of the matrix at the distal end has exposed the septa and one of the wide, complete tabulae. The exterior has been weathered, but shows faint, closely set vertical striations.

Internal features: A series of sections have been made from two nonsilicified paratypes. There are between 80 and 90 septa of which the major extend approximately halfway to the axis. The alternate minor septa are very thin and extend less than 5 mm. from the periphery. The dissepiments are confined to a single series forming a ring at a distance ranging from 2 to 3 mm. from the periphery. The tabularium occupies almost the entire diameter of the coral and is composed of complete tabulae, which are alternately horizontal and proximally convex. Along their peripheral terminations is a single row of small, axially convex dissepiments.

Remarks: In its external appearance *A. nevadensis* is very similar to *A. yandelli* in that both species are characterized by the funnel-shaped growth expansion. *A. nevadensis* is distinguished by the more strongly developed septa and by the ring of dissepiments. The septa in *A. yandelli* have been reduced to mere peripheral spines and are entirely devoid of dissepiments.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94444.
Paratype: U. S. Nat. Mus., 94444*a*.

AMPLEXUS LONENSIS Stumm, n. sp.
Plate 53, figure 4; plate 54, figure 4

Exterior features: The holotype is a large trochoid coral, which is complete except for the calyx, and which measures 7 cm. in length and expands from a narrow base to a diameter of 4 cm. at the distal end. The exterior is covered with an epitheca that is vertically striated by parallel rugae slightly less than 1 mm. apart.

Internal features: There are approximately 86 septa of which the major range from 4 to 7 mm. in length and extend from one-third to almost one-half the distance to the axis. The alternate minor septa are about one-half the length of the major. All the septa are dilated peripherally and attenuated axially. Dissepiments are few and irregularly spaced and are usually axially convex. The tabulae are complete and horizontally disposed, separated by average distances of 1 mm. They are bounded along the periphery by a narrow zone of large, irregular dissepiments. In the mature stage of the coral the tabularium averages 2 cm. in diameter, and the peripheral dissepimentarium range from 2 to 3 mm. in diameter.

Remarks: The size and the trochoid growth habit of this species are unusual for *Amplexus* and suggest a Zaphrentoid or Cyathophylloid type. Nevertheless, the short septa and wide, complete tabulae are characteristic of *Amplexus*. As S. Smith has noted, *Amplexus* ranges from the Silurian to the Carboniferous and, therefore, is very likely a polyphyletic genus. The trend toward axial shortening of the septa may have originated in different lineages at different times. This might account for the difference in external appearance in the different species.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94445.
Paratype: U. S. Nat. Mus., 94445*a*.

AMPLEXUS MAGNUS Stumm, n. sp.
Plate 53, figure 5; plate 54, figure 5

External features: The holotype is the central portion of a large cylindroid coral that averages 3 cm. in diameter. The length of the specimen is almost 3.5 cm. Weathering has removed the epitheca to a great extent, but faint vertical striations can be seen in places. Growth

annulations are small and widely separated. From several fragmentary specimens it can be seen that the species expanded rapidly from the base of attachment and assumed its cylindroid growth form at an early stage.

Internal features: There are approximately 110 short septa which dilate at their peripheral ends to form a narrow stereozone 2 mm. in diameter. Between this peripheral stereozone and their axial terminations, the septa are very thin. The major septa extend about one-third of the distance to the axis, averaging 8 mm. in length. The alternate minor septa range from 4 to 7 mm. in length, and are, in places, difficult to distinguish from the major. Dissepiments are relatively numerous between the septa and are irregular in habit, ranging in different places from horizontal to oblique to strongly arcuate. The tabulae are complete and horizontal, averaging almost 3 cm. in length, and separated by distances ranging from 1 to 2 mm. The peripheral zones of dissepiments are variable in size, being more strongly represented where the growth expansions, occur. They range from 3 to 7 mm. in diameter, and are composed of dissepiments which are large and very irregular in shape.

Remarks: This species, while having the cylindroid habit characteristic of most forms of *Amplexus*, is much larger and has a correspondingly greater number of septa than any other cylindroid forms assigned to Devonian species of this genus. The strongly developed dissepimental tissues are also unusual. However, as in *A. lonensis*, the short septa and the wide, complete tabulae are the deciding characters in the assignment of this species.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94446.

Paratype: U. S. Nat. Mus., 94446*a*.

NEVADAPHYLLUM Stumm, n. gen.

Simple, cylindroid corals with a smooth epitheca and very heavy transverse growth annulations. The septa are of two orders of which the major extend all the way to the axis, becoming twisted at their axial ends. The alternate minor septa are short, with spinose axial terminations, and are usually one-third the length of the major. All the septa dilate and lie in contact at the periphery, forming a pronounced stereozone averaging 1 cm. in diameter. A fossula, characterized by a swollen, club-shaped axial end, is present. Irregular dissepiments are numerous between the septa. The tabulae are very closely set, usually incomplete and irregularly twisted, forming an anastomosing network.

Genotype: *Nevadaphyllum masoni*.

NEVADAPHYLLUM MASONI Stumm, n. sp.
Plate 53, figure 6; plate 54, figure 6

External features: The holotype is the central portion of a large cylindroid coral with an average diameter of 4.5 cm. The specimen measures approximately 4 cm. in length. The exterior is ribbed with heavy transverse annulations, which increase the diameter of the specimen by as much as 5 mm. Portions of the epitheca that have not been removed by weathering do not show vertical striations.

Internal features: There are about 150 septa, of which the major extend from the periphery all the way to the axis, becoming twisted at their axial terminations. The alternate minor septa extend one-third the distance to the axis, dying out as sharply attenuated spines. All the septa become so strongly dilated as they approach the periphery that they are in contact laterally, producing a solid stereozone 1 cm. in diameter. A prominent fossula is produced by the abortion of the cardinal septum. The peripheral portion of this fossula is obliterated by the stereozone. The fossula increases in diameter as it ap-

proaches the axis, dilating at its axial end and becoming club-shaped. The major septa become gradually attenuated from the peripheral stereozone to their axial terminations, but are much thicker than the minor, which become rapidly very attenuated inward from the stereozone and die out as thin spines within a distance of 5 mm. Interseptal dissepiments are fairly numerous between the stereozone and a point 1 cm. from the axis. They are either horizontal, convex, or irregularly oblique. The tabulae are usually incomplete and are very wavy and irregular, terminating abruptly against the solid peripheral stereozone. They are so closely set that they are almost in contact.

Remarks: *Nevadaphyllum* has probably developed from a Zaphrentoid ancestor, as the disposition of the septa and the dissepiments indicates, but has developed a heavy peripheral stereozone and has assumed a cylindroid form. The fossula, with its swollen axial end is also an unusual development, being the only one of this type that the author has seen in Devonian lineages. It is present in *Palaeosmilia*, a Carboniferous genus of Cyathophylloid origin that is common in the Mountain limestone of sub-Carboniferous age in England.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94447.

Paratype: U. S. Nat. Mus., 94447*a*.

PAPILIOPHYLLUM Stumm, n. gen.

Simple, trochoid corals with erect calyces and vertically striated epitheca. A peripheral zone of dissepiments increases in diameter from the proximal to the distal extremity. A prominent fossula is produced by the abortion of the cardinal septum. The septa of the two cardinal quadrants are greatly thickened by stereoplasm, forming a heavy stereozone. These septa are usually in lateral contact. The septa of the two counter quadrants, on the other hand, are very thin throughout their length. All the septa terminate peripherally against the dissepimental zone and extend to the axis, there being no differentiation into a major and minor series. Horizontal dissepiments are present between the septa of the counter quadrants. The tabulae are incomplete, closely set, and inclined upwards as they approach the thickened septa of the cardinal quadrants.

Genotype: *Papiliophyllum elegantulum*

PAPILIOPHYLLUM ELEGANTULUM
Stumm, n. sp.
Plate 53, figure 7; plate 54, figure 7

External features: The holotype is the central portion of a curved trochoid coral measuring 3 cm. in length, and expanding from a diameter of 2.5 cm. at the base to 4 cm. at the distal end. The epitheca is vertically striated and banded with occasional faint transverse growth annulations. Both the proximal and distal ends are missing.

Internal features: A series of thin sections taken at various growth stages present an unusual growth habit. In the mature stage a transverse section shows a peripheral border of axially convex dissepiments that averages 1 cm. in diameter. The septa, which are not separable into a major and minor series, extend from the inner border of this zone to the axis. The septa lying within the cardinal quadrants are so greatly thickened that they are in lateral contact, forming a solid stereozone. A pronounced fossula is produced by the abortion of the cardinal septum. In the counter quadrants, the septa are very thin and are separated by interseptal spaces averaging 1 mm. in diameter. These interseptal spaces are filled with horizontal dissepiments. A transverse section cut near the base of a paratype shows that the septal arrangement is the same, but the peripheral dissepimental zone is lacking. In a section cut 1 inch above the base of another paratype, the dissepimental zone is present along the peripheral edge of the counter

quadrants. It seems, therefore, that the peripheral zone of dissepiments appears in the later growth stages, and is produced at an earlier stage along the counter quadrants. In a transverse section through the calyx of another paratype, the septa in the cardinal quadrants become slightly thinner, and the resulting interseptal spaces contain a few transverse dissepiments. A longitudinal section shows the peripheral dissepimentarium increasing in diameter toward the distal end. The area of the cardinal quadrants is represented by a solid stereozone. The region occupied by the counter quadrants shows a series of short, incomplete tabulae inclined upwards against the cardinal stereozone. This zone of tabulae averages 1.5 cm. in diameter.

Remarks: Although coral genera with a peripheral dissepimentarium are common, and genera with dilated septa in the cardinal quadrants are known, specimens showing both these characters, together with a pronounced fossula and Zaphrentoid dissepiments in the area of the counter quadrants present an entirely new combination of trends that is far in advance of the majority of the genera commonly included in the Zaphrentidae.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: Cornell Univ.

Paratypes: Cornell Univ.

Paratypes: U. S. Nat. Mus., 94448.

EUREKAPHYLLUM Stumm, n. gen.

Simple, trochoid corals with vertically striated epitheca. A peripheral zone of very large, irregular dissepiments increases in diameter toward the distal extremity. Usually this zone is crossed by short, discontinuous septal crests. The septa extend from the inner side of this zone about halfway to the axis, leaving a wide unoccupied space in the central portion of the coral. The septa of the cardinal quadrants are dilated but not to the extent that they are in lateral contact. An indistinct fossula is produced by a shortened cardinal septum. The septa in the counter quadrants are very thin. Interseptal dissepiments are lacking or very rare. The tabulae are complete and horizontal or proximally convex, and are separated by wide unoccupied spaces.

Genotype: *Eurekaphyllum breviseptatum.*

EUREKAPHYLLUM BREVISEPTATUM
Stumm, n. sp.
Plate 53, figure 8; plate 54, figure 8

External features: The holotype is a curved trochoid coral, measuring 4.5 cm. in length and expanding from a pointed base to a diameter of over 3.5 cm. at the distal end. The calyx has been removed by weathering. The epitheca is vertically striated, and displays faint transverse growth annulations.

Internal features: A transverse section shows a peripheral zone averaging 6 mm. in diameter, which is occupied by very large, irregularly spaced dissepiments. These dissepiments have the appearance of wavy lines, and, in places, are almost 2 cm. in length. This zone is crossed by short, discontinuous septal crests, on which the former peripheral extent of the septa can be traced. In a few places these crests connect with the inner septal zone. The septa extend from the inner border of the peripheral zone less than halfway to the axis, leaving an unoccupied space 1.5 cm. in diameter at the center of the coral. The septa average 7 mm. in length. In the cardinal quadrants the septa are slightly dilated, and the cardinal septum is aborted, producing an obscure fossula. The septa in the counter quadrants are very thin. Interseptal dissepiments are almost entirely lacking between the septa. Only five can be seen in the transverse section. The tabulae are complete and usually proximally convex, separated by distances ranging from 2 to 8 mm. The entire tabularium averages 1.3 cm. in diameter. It is bounded along the cardinal side

by the stereozone produced by the dilated septa, and along the counter side by a series of irregular dissepiments averaging 1 cm. in diameter.

Remarks: This species, in addition to a peripheral dissepimentarium, has developed an Amplexoid septal habit with the corresponding wide, complete tabulae. As a whole the internal structure is very unlike any other Zaphrentoid or Amplexoid forms hitherto described, as far as the author has been able to determine.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94449.

Family CYATHOPHYLLIDAE Milne-Edwards and Haime, 1850

Genus GRYPOPHYLLUM Wedekind, 1922 (7)

Genotype: By original designation *Grypophyllum denkmanni* Wedekind, op. cit.

GRYPOPHYLLUM NEVADENSE Stumm, n. sp.
Plate 53, figure 9; plate 55, figure 1

External features: The holotype is a simple, curved trochoid coral with the distal portion including the calyx removed by weathering. The specimen is 3.5 cm. long with a minimum diameter of 4 mm. at the proximal end expanding to over 3 cm. at the distal end. There is a thin vertically striated epitheca displaying a few slight transverse growth annulations. The vertical striations are separated by an average distance of 1 mm.

Internal features: There are about 100 thin, radially arranged septa of which the major nearly reach the axis. A faint, degenerate fossula, only visible at the axial end, is preserved. The alternate minor septa are very thin, in places discontinuous, and extend less than half way to the axis. Horizontal, oblique, or peripherally convex dissepiments are numerous from the periphery to the terminations of the minor septa and are fewer and more widely spaced between the major septa beyond the axial ends of the minor. The distance between the septa ranges from 0.5 to 0.7 mm. A longitudinal section shows a tabularium averaging 2 cm. in diameter in which a series of closely set, alternately complete and incomplete tabulae can be seen. The tabularium is bounded on either side by peripheral zones ranging from 2 to 4

EXPLANATION OF PLATE 54

All figures natural size

FIGS. *1a–c—Heterophrentis nevadensis* Stumm, n. sp., *1a*, transverse section of holotype; *1b*, transverse section of a paratype; *1c*, longitudinal section of a paratype. (p. 426)
2a–c—Amplexus invaginatus Stumm, n. sp., *2a*, transverse section of holotype; *2b*, transverse section of a paratype; *2c*, longitudinal section of a paratype. (p. 427)
3a–c—Amplexus nevadensis Stumm, n. sp., *3a*, transverse section of a paratype; *3b*, transverse section of another paratype; *3c*, longitudinal section of a paratype. (p. 427)
4a, b—Amplexus lonensis Stumm, n. sp., *4a*, transverse section of holotype; *4b*, longitudinal section of a paratype. (p. 428)
5a, b—Amplexus magnus Stumm, n. sp., *5a*, transverse section of holotype; *5b*, longitudinal section of a paratype. (p. 428)
6a, b—Nevadaphyllum masoni Stumm, n. sp., *6a*, transverse section of holotype; *6b*, longitudinal section of a paratype. (p. 429)
7a–e—Papiliophyllum elegantulum Stumm, n. sp., *7a*, transverse section of holotype; *7b*, transverse section of a paratype cut 1 inch above base; *7c*, transverse section of another paratype cut ¼ inch above base; *7d*, transverse section of another paratype cut through calyx; *7e*, longitudinal section of a paratype. (p. 430)
8a, b—Eurekaphyllum breviseptatum Stumm, n. sp., *8a*, transverse section of holotype; *8b*, longitudinal section of holotype. (p. 431)
9a, b—Grypophyllum giganteum Stumm, n. sp., *9a*, transverse section of holotype; *9b*, longitudinal section of holotype. (p. 433)

Stumm, Devonian Tetracorals

UNIV. OF MICH.

mm. in diameter, composed of small, axially convex dissepiments.

Remarks: Wedekind established the genus *Grypophyllum* to designate those Cyathophylloid corals in which the secondary septa were not well developed. The Nevada specimens here referred to this genus have an internal structure quite similar to that characteristic of Wedekind's species.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94450.

Paratype: U. S. Nat. Mus., 94450*a*.

GRYPOPHYLLUM GIGANTEUM
Stumm, n. sp.
Plate 54, figure 9

External features: The holotype is a large trochoid coral with both the proximal and distal ends missing. The specimen expands from 4.5 to 5.5 cm. in a vertical distance of 6 cm. The exterior surface has been weathered so that the peripheral terminations of the septa are embossed on the surface.

Internal features: There are about 120 thin septa, of which the major nearly reach the axis, becoming irregular and wavy at their axial terminations. The minor septa are extremely variable, some extending about halfway to the axis, others appearing as short peripheral spines. In places they reappear as short, discontinuous crests. The septa are separated by an average distance of 1.5 mm. Dissepiments are more evenly spaced between the periphery and the axial terminations of the primary septa, not showing the crowded series where the minor septa are represented—a characteristic feature of *G. nevadense*. A great majority of the dissepiments are, however, very irregular in structure. They are in places strongly arched or V-shaped, in others incomplete and abutting against one another. A longitudinal section shows a tabularium averaging 3 cm. in diameter in which occasional horizontal, complete tabulae are interspersed with proximally arched tabellae. There is a peripheral dissepimentarium ranging from 5 to 7 mm. in diameter composed of small axially convex dissepiments.

Remarks: The minor septa in this species are quite typical of the genus *Grypophyllum* as described by Wedekind. The alternation of complete horizontal tabulae with arched tabellae is also characteristic of the genus. This is a much larger form than any other previously described.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94451.

GRYPOPHYLLUM CURVISEPTATUM
Stumm, n. sp.
Plate 55, figure 2

External features: The holotype is a fragment of a ceratoid or trochoid coral, measuring 4 cm. in length and averaging 3.5 cm. in diameter. Weathering has removed the epitheca and has exposed the peripheral terminations of the septa.

Internal features: A transverse section shows about 100 septa of which the minor are very thin and extend approximately one-third the distance to the axis. The major septa are heavier and at the point where the minor septa terminate they become strongly twisted in the manner exhibited by *Streptelasma* to form a confused mass in the axial region. A faint fossula is produced by a shortened cardinal septum. The dissepiments are numerous and relatively horizontal between the periphery and the axial terminations of the minor septa. They are very sparsely represented beyond this point between the twisted major septa. As shown in the longitudinal section the tabulae are concave upward and are usually incomplete. The tabularium averages 2 cm. in diameter, and is bounded at the peripheral terminations by zones averaging 1 cm. in diameter, composed of elongated, slightly axially convex dissepiments.

Remarks: The extreme twisting of the axial portions of the major septa as exhibited by this species is quite rare in the Cyathophyllidae. Despite this unusual character, the species shows a close relationship to the type of structure characteristic of *Grypophyllum* as is shown by the short, thin minor septa, and the closely set incomplete tabulae.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94452.

Genus TABULOPHYLLUM Fenton and Fenton, 1924 (8)

Genotype: By original designation, *Tabulophyllum rectum* Fenton and Fenton, op. cit.

TABULOPHYLLUM NEVADENSE Stumm, n. sp. Plate 55, figure 4

External features: The holotype is a small trochoid coral, measuring 3 cm. in length, and expanding from a pointed base to a diameter of slightly more than 2 cm. at the distal end. The calyx is missing. There is a thin epitheca with faint closely set vertical striations and small but sharply ribbed transverse growth annulations.

Internal features: In the transverse section there are 56 straight, thin, radially arranged septa of which the major extend to the axis and the minor are almost as long. In places it is difficult to distinguish the two septal series. The septa do not quite reach the periphery, but are separated by a zone of axially convex dissepiments. This peripheral dissepimental zone ranges from 2 to 4 mm. in diameter in different parts of the coral. Horizontal or peripherally convex dissepiments are closely spaced between the septa. A longitudinal section shows a tabularium averaging almost 2 cm. in diameter which is composed of a series of short, discontinuous tabellae that are usually proximally convex. This zone is bounded on either side by areas of small, axially convex dissepiments, which range in diameter from 2 to 4 mm.

Remarks: *Tabulophyllum* was established by Fenton and Fenton to designate those Cyathophylloid corals that have developed a peripheral dissepimentarium and whose tabulae are occasionally complete, but usually are broken up into short tabellae. *Tabulophyllum nevadense* is similar in external form to *T. rectum*, the genotype of *Tabulophyllum*, but is distinguished by the longer axial extent of the septa and the more closely packed dissepiments. In *T. rectum* there are occasional complete tabulae between the series of incomplete tabellae, which is another distinguishing character from *T. nevadense*, in which the discontinuous tabellae occupy the entire tabularium.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: Cornell Univ.

Genus CYATHOPHYLLUM Goldfuss, 1826 (9)

Genotype: By subsequent designation of King, 1849 (10) *Cyathophyllum plicatum* Goldfuss, 1826 (op. cit.).

Remarks: The validity of the genus *Cyathophyllum* is, at the present time, in an unsettled state. Lang and Smith 1929 (11) quote the following:

> Dana, 1846, p. 183, said, "the type of this genus is the *Cyathophyllum dianthus*. See Murchison's Silurian System, pl. 16, figs. 12, 12b; also figs. 9, 10, 11a . . . ," and nowhere mentioned Goldfuss as author of this species. Although Lonsdale in Murchison (loc. cit.) called the corals that he figured as 12, 12b *Cyathophyllum dianthus*, they represent at least three Silurian species . . . , none of which is conspecific with *C. dianthus* Goldfuss. Dana's lectotype, therefore, is not valid. Edwards and Haime (1850, p. 68) cited as lectotype *Cyathophyllum helianthoides* Goldfuss, pl. 20, fig. 2, Devonian, Eifel; but they were anticipated by King (1849, p. 388), who chose *Cyathophyllum plicatum*, pl. 15, fig. 12. The identity of this species is, however, very obscure, and, until it is established, *Cyathophyllum* cannot be properly used.

The species here provisionally referred to *Cyathophyllum* is so placed because, in the author's opinion, it is characteristic of what has been considered "typical" Cyathophylloid structure by most authors in this country, and because it would be inappropriate to propose a new name for this type of structure until the characters of *Cyathophyllum plicatum* have been definitely determined.

CYATHOPHYLLUM? LONENSE
Stumm, n. sp.
Plate 55, figure 3

External features: The holotype is a simple, trochoid coral, measuring 2 cm. in length, and expanding from a narrow base to a diameter of 2.5 cm. at the distal end. The specimen was originally much longer, but weathering has removed much of the distal portion. The exterior has been weathered to expose the peripheral structures. The ends of the parallel, vertical septa can be seen, separated by series of horizontal dissepiments.

Internal features: In the transverse section there are about 82 thin, radially arranged septa, which are separated by interseptal spaces averaging 1 mm. in diameter. The major septa extend to the axial region, becoming slightly twisted at their axial terminations. The alternate minor septa average two-thirds the length of the major. Peripherally convex dissepiments are very numerous between the septa as far toward the center of the coral as the axial terminations of the minor septa. From this point to the axial ends of the major septa they are more sparsely represented, and many of them lose their peripherally convex outline. The tabularium averages 1.5 cm. in diameter and is composed of tabulae that have been broken up into incomplete tabellae by the axial extensions of the major septa. These tabellae are proximally convex and are separated by distances ranging from 1 to 1.5 mm. apart. The tabularium is bounded by peripheral zones averaging 9 mm. in diameter, which are composed of small, axially convex dissepiments.

Remarks: This species is characteristic of what has been regarded as typical "Cyathophylloid" structure, as exemplified by the thin, radially arranged septa with crowded dissepiments and no fossula. Many of the species assigned to this genus from eastern North America are distinguished by a greater irregularity in the structure of the interseptal dissepiments as shown by the illustration of *C. robustum* Hall 1876 (12). However, the species *C. anticostiense* Billings and *C. interruptum* Billings as illustrated by Lambe 1901 (13), show a dissepimental structure very similar to that exhibited by *C. lonense*.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus. 94453.

Genus SPONGOPHYLLUM Milne-Edwards and Haime, 1850 (14)

Genotype: By monotypy, *Spongophyllum sedgwicki* Milne-Edwards and Haime (op. cit.).

SPONGOPHYLLUM NEVADENSE
Stumm, n. sp.
Plate 53, figure 10; plate 55, figure 5

External features: The holotype is a compound, phaceloid corallum, approaching the cerioid habit where crowded. The corallites are usually cylindroid, occasionally polygonal along one or two sides when in contact with one another. They average 6 mm. in diameter and exhibit fine vertical striations and delicate, closely spaced growth annulations.

Internal features: A transverse section shows the corallites, round when separate, becoming flattened or concave where in contact with others. There are from 30 to 34 septa, of which the major extend almost to the axis. The alternate minor septa are very short, usually represented by peripheral spines, oc-

casionally entirely lacking. They never extend more than 1 mm. from the periphery. Dissepiments are few and irregularly spaced. In some corallites they form a thin ring halfway between the periphery and the axis. The tabulae are complete and relatively horizontal, averaging 3 mm. in width, and separated by a distance averaging 0.8 mm. They are bounded along the periphery by a narrow zone composed of one or two rows of axially convex dissepiments.

Remarks: The genotype of *Spongophyllum* is a cerioid coral, but as Schlüter 1881 (15) has shown, this type of structure also occurs in coralla that are partially or completely phaceloid in habit. *S. nevadense* is transitional between the phaceloid and the cerioid growth habits and possesses the typical internal structure of the genus.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94454.

SPONGOPHYLLUM EXPANSUM
Stumm, n. sp.

Plate 53, figure 11; plate 55, figure 6

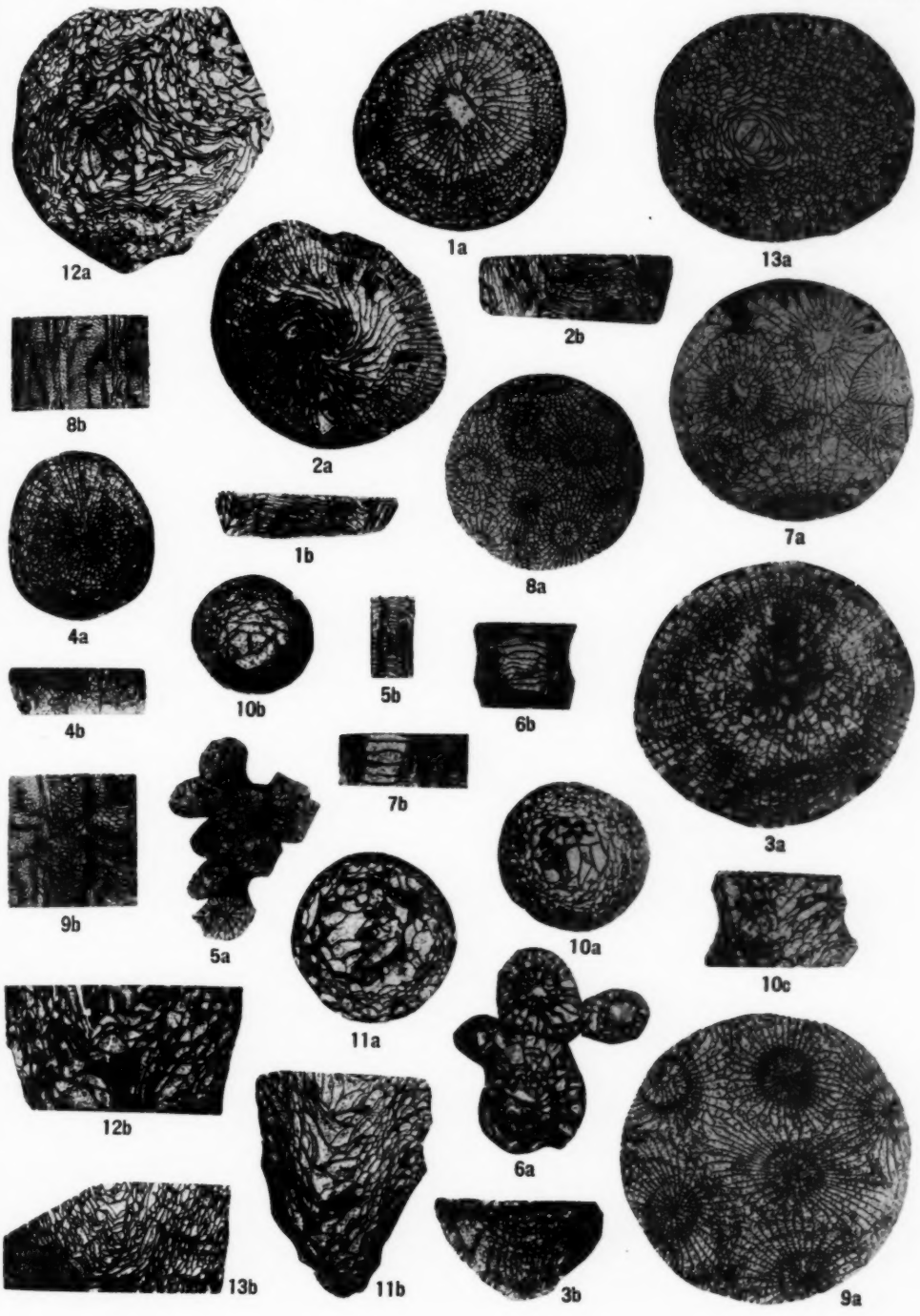
External features: The holotype is a phaceloid corallum, becoming partially cerioid at the points where growth expansions unite the individual corallites. The individual corallites are cylindrical, and range from 10 to 15 mm. in diameter except where the lateral expansions occur. These expansions increase the diameter of the corallites by as much as 1 cm., usually causing lateral contact. They are separated by distances averaging 3 cm. The corallites are covered with a heavy epitheca that is deeply vertically striated.

Internal features: There are from 40 to 44 septa in the corallites, of which the major extend almost to the axis. The minor septa are usually feebly developed as peripheral spines, but occasional longer ones extend halfway to the axis. All the septa are thin throughout their length. Dissepiments are few, the majority of them being gathered to form a

EXPLANATION OF PLATE 55

All figures natural size

FIGS. *1a, b—Grypophyllum nevadense* Stumm, n. sp., *1a*, transverse section of holotype) *1b*, longitudinal section of a paratype. (p. 432;
2a, b—Grypophyllum curviseptatum Stumm, n. sp., *2a*, transverse section of holotype; *2b*, longitudinal section of holotype. (p. 433)
3a, b—Cyathophyllum? lonense Stumm, n. sp., *3a*, transverse section of holotype; *3b*, longitudinal section of holotype. (p. 435)
4a, b—Tabulophyllum nevadense Stumm, n. sp., *4a*, transverse section of holotype; *4b*, longitudinal section of a paratype. (p. 434)
5a, b—Spongophyllum nevadense Stumm, n. sp., *5a*, transverse section of holotype; *5b*, longitudinal section of one of the corallites of the holotype. (p. 435)
6a, b—Spongophyllum expansum Stumm, n. sp., *6a*, transverse section of a portion of the holotype; *6b*, longitudinal section of one of the corallites of the holotype. (p. 436)
7a, b—Prismatophyllum kirki Stumm, n. sp., *7a*, transverse section of holotype; *7b*, longitudinal section of one of the corallites of the holotype. (p. 437)
8a, b—Radiastraea arachne Stumm, n. sp., *8a*, transverse section of holotype; *8b*, longitudinal section of holotype. (p. 439)
9a, b—Billingsastraea billingsi nevadensis Stumm, n. var., *9a*, transverse section of holotype; *9b*, longitudinal section of holotype. (p. 438)
10a–c—Mesophyllum robertsense Stumm, n. sp., *10a*, transverse section of holotype; *10b*, transverse section of a paratype; *10c*, longitudinal section of a paratype. (p. 440)
11a, b—Mesophyllum lonense Stumm, n. sp., *11a*, transverse section of holotype; *11b*, longitudinal section of a paratype. (p. 440)
12a, b—Mesophyllum flexum Stumm, n. sp., *12a*, transverse section of holotype; *12b*, longitudinal section of holotype. (p. 441)
13a, b—Mesophylloides kirki Stumm, n. sp., *13a*, transverse section of holotype; *13b*, longitudinal section of holotype. (p. 441)



Stumm, Devonian Tetracorals

UNIV. OF MICH.

ringlike structure halfway between the periphery and the axis. The tabulae are complete and horizontal, averaging 8 mm. in width. A single or double row of distally arched dissepiments occurs at each peripheral extremity.

Remarks: This species, although much larger than any other species heretofore assigned to *Spongophyllum*, has the typical internal structure of the genus. The typical characters of the genus are the thin septa separated by wide interseptal spaces and occasionally separated from the periphery by dissepiments. The minor septa are usually very short, appearing as degenerate peripheral spines. The tabulae are complete and horizontal, and the peripheral zone of dissepiments is narrow, usually confined to a single row.

Horizon and locality: Basal 500 feet of the Nevada limestone, near mouth of Frazier Creek, north end of Roberts Mountains, Roberts Mountains Quadrangle, Nevada.

Holotype: U. S. Nat. Mus., 94455.

Genus PRISMATOPHYLLUM Simpson, 1900 (16)

Genotype: *Cyathophyllum rugosum* Milne-Edwards and Haime, 1851 (17), now *Prismatophyllum prisma* Lang and Smith, 1935 (18).

PRISMATOPHYLLUM KIRKI Stumm, n. sp.
Plate 55, figure 7

External features: The holotype is a fragment of a compound cerioid corallum in which the individual corallites range from 1 to 3 cm. in diameter. The exterior of the corallum has been weathered and covered with a deposit of secondary calcite that conceals the calyces and the epitheca.

Internal features: The corallites are bounded by a strong polygonal outer wall. In many places this wall has a curved or an irregular outline. There are from 36 to 40 thin septa, which are slightly crenulate and which are separated by interseptal spaces ranging from 1 to 2 mm. in width. The major septa extend from the peripheral wall and terminate a short distance from the axis. The minor septa are very discontinuous, in places represented only by short peripheral spines, in others appearing as disconnected septa crests at some distance from the periphery. In the places where the minor septa are represented, the interseptal dissepiments are peripherally convex. Where the minor septa are missing, the dissepiments become incomplete and abut against one another in a confused network. Many of the minor septa reappear as crests at a point 5 mm. from the axes of the corallites. At this point there is a crowded series of small dissepiments forming an inner wall. This wall is only well developed in the mature corallites. The tabulae are complete and horizontal, averaging 7 mm. in length, and are separated by uniform distances of 2 mm.

Remarks: The typical species of *Prismatophyllum* have more closely set septa, the minor averaging two-thirds the length of the major; closely crowded, horizontal or peripherally convex dissepiments, the incomplete tabulae composed of a horizontal axial series with an inclined periaxial series on each side. *P. kirki*, with its wide, complete tabulae and discontinuous minor septa is easily distinguished from other species of the genus. It may be that *P. kirki* may have developed from a different stock and, therefore, deserves a separate generic standing. In order to prove this point, more material with which to study the developmental stages will be necessary.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94456.

Genus BILLINGSASTRAEA Grabau, 1927 (19)

Genotype: By original designation of Grabau (op. cit.), *Phillipsastraea verneuili* Milne-Edwards and Haime, 1851 (20).

Remarks: Grabau (op. cit.), quoted *Phillipsastraea* (*Billingsastraea*) *verneuili* in a fossil list without including a subgeneric description. It is quite evident, however, that *P. verneuili*, and the larger form *P. billingsi* Calvin, 1893 (21) (*P. gigas* auctt.), with which it is usually associated, are quite unlike *Phillipsastraea* as represented by the genotype, *P. hennahi* (Lonsdale). *Billingsastraea* deserves full generic standing. The following generic description is based on authentic specimens of *B. verneuili* and on the holotype of *B. billingsi*.

Compound, astraeoid coralla, developed from Heliophylloid ancestors, in which the individual corallites are not bounded by walls, but whose septa are confluent or abut against one another at their peripheral extremities. The septa are thin, radially ranged, and heavily carinate, with typical cross-bar carinations. The major septa extend to the axes and the alternate minor septa are from one-half to one-third as long. In many specimens a faint inner wall is produced by a crowded series of dissepiments coinciding with the axial terminations of the minor septa. Horizontal or peripherally convex dissepiments occupy the interseptal spaces. The tabulae are confined to a narrow axial region, and are usually broken up into short, horizontal tabellae by the axial portions of the major septa.

Remarks: *Billingsastraea* can be distinguished from *Phillipsastraea* by the following characters: In the latter genus, an inner wall is produced by dilation of the septa at the margin of the tabularium while in *Billingsastraea* the septa are thin throughout their length, and any inner wall that may be present is caused by a crowding of the dissepiments. The heavy, cross-bar carinae characteristic of *Billingsastraea* are not found in *Phillipsastraea*, although certain species of the latter genus bear spinose crenulations. The tabulae of *Billingsastraea* consist of horizontal tabellae, while in *Phillipsastraea* the tabulae are complete or incomplete, not intercepted by the axial ends of the major septa and have a specialized row of horse-shoe-shaped dissepiments along each side. *B. verneuili* can be distinguished from the larger species, *B. billingsi*, only on the basis of relative size. The corallites in the former range from 1 to 1.5 cm. in diameter, and those in the latter from 2 to 4.5 cm., with a corresponding larger number of septa. In all other respects the two species are identical. The specimen illustrated by Hall, 1876 (22), as *Heliophyllum confluens* is an example of *Billingsastraea billingsi*.

BILLINGSASTRAEA BILLINGSI NEVADENSIS Stumm, n. var.

Plate 53, figure 12; plate 55, figure 9

External features: The holotype is a compound astraeoid corallum in which the individual corallites range from 1 to 2.5 cm. in diameter. There are from 36 to 42 radially arranged septa in the corallites, with an average of 40 in those of mature size. Each of the corallites bears a depressed central pit, which is usually 5 mm. in diameter and is bounded along its rim by the axial terminations of the minor septa.

Internal features: The septa are confluent or abut against one another at their peripheral ends. They are thin throughout their length and are carinate, but the carinations are different from those characteristic of *B. billingsi* in that they are separated by greater distances, and in that many of them extend outward from only one side of the septum, giving many of the septa the appearance of wavy lines. On other septa occasional typical cross-bar carinae can be seen. Peripherally convex dissepiments are numerous, and a crowded series of them forms an inner wall that corresponds to the margin of the central pit as seen on the exterior. The dissepiments are much more numerous and the inner walls much more heavily defined that in the typical specimens of *B. billingsi*.

The tabulae are confined to a narrow axial area corresponding to the central

pits, and are broken up into short horizontal or inclined tabellae by the axial portions of the major septa, which can be seen in the longitudinal section as vertical wavy lines intercepting the tabulae.

Remarks: In its general appearance this variety is quite similar to *B. billingsi*, but, as described above, can be distinguished by the difference in the structure of the carinae, by the greater profusion of the interseptal dissepiments, and by the more pronounced dissepimental inner wall.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus. 94467.

RADIASTRAEA Stumm, n. gen.

Compound astraeoid coralla with radially symmetrical septa. The septa of adjoining corallites are either confluent or abut against one another at their peripheral extremities. Slight traces of epithecal tissue can be seen in places between the corallites. The major septa extend to the axis, usually deflecting at their axial ends to form a small tubular ring. The alternate minor septa average two-thirds the length of the major. All the septa are thin, and do not bear carinae. Horizontal and peripherally convex dissepiments are very numerous between the septa. A crowded series composed of 3 or 4 rings of dissepiments forms an inner wall at the point where the minor septa terminate. The tabulae are divided into an axial series of horizontal tabellae, bounded on either side by a series of distally inclined tabellae. The central, horizontal tabellae are separated from the inclined series by a wall produced by the deflected axial ends of the major septa.

Genotype: *Radiastraea arachne.*

RADIASTRAEA ARACHNE Stumm, n. sp.
Plate 53, figure 13; plate 55, figure 8

External features: The holotype is a portion of a compound hemispherical corallum composed of radially arranged astraeoid corallites whose inner walls are represented on the distal surface of the corallum by exsert rims. The number of septa in the coralites ranges from 28 to 34, of which the major extend to the axial regions and the minor terminate at the inner wall. At their peripheral ends, the septa are occasionally confluent with those of neighboring corallites, but usually abut against them. The diameters of the coralites range from 8 to 11 mm., and the diameters of the inner walls average 3.5 mm. The extrathecal tissues are very evenly developed so that the inner walls lie at an average of 8 mm. apart.

Internal features: The major septa extend almost to the axis, but become deflected at their axial ends to form a tubular ring less than 1 mm. in diameter at the center of the corallites. The minor septa terminate abruptly at the inner walls. In places faint traces of a degenerate epitheca can be seen between the corallites, but usually the septa are confluent or abutting at their peripheral ends. All the septa are thin and smooth, bearing no carinae. Dissepiments are very numerous between the septa, and where the minor septa terminate, a crowded series of them forms the inner wall. The tabularium occupies a central area corresponding in size to the diameter of the inner walls of the corallites. It is composed of an axial series of horizontal tabellae averaging 1 mm. in diameter, bounded on either side by a series of distally inclined tabellae that average 1.5 mm. in diameter. The central horizontal tabellae are separated from the inclined series on either side by a wall composed of the deflected axial ends of the major septa.

Remarks: In the possession of the tubular axial wall *Radiastraea* resembles the genus *Aulina* S. Smith 1917, from the Lower Carboniferous Mountain limestone of England. *Aulina*, however, possesses dilated septa similar to those of *Phillipsastraea*, while there is no trace of septal dilation in *Radiastraea*.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Moun-

tain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94458.

Family CYSTIPHYLLIDAE Milne-Edwards and Haime, 1850

Genus MESOPHYLLUM Schlüter, 1889 (23)

Genotype: By subsequent designation of Wedekind, 1925 (24), *Mesophyllum defectum* Schlüter, 1889 (op. cit.), = *Cyathophyllum vesciculosum* Goldfuss, 1826 (25) = *Cystiphyllum vesciculosum* auctt.

MESOPHYLLUM ROBERTSENSE Stumm, n. sp.

Plate 53, figure 14; plate 55, figure 10

External features: The holotype is a simple, cylindroid coral with a heavy epitheca, which is faintly vertically striated, and annulated with a closely crowded series of circumferential growth lines. The vertical striations are separated by an average distance of 1.5 mm. Weathering has removed the proximal termination of the specimen, but the distal end is complete and displays a calyx with erect walls through which a small individual has budded by calycinal rejuvenescence. The interior of the calyx of the bud has been obscured by a deposition of secondary calcite. The length of the specimen is 8 cm.; the diameter at the base, 12 mm.; and the diameter at the calyx 15 mm.

Internal features: Transverse sections show that the dissepimentarium and the tabularium are very distinctly separated. The dissepimentarium extends from the periphery about halfway to the axis, having an average width of 6 mm., and is composed of small, axially convex dissepiments. The tabularium, comprising the central portion of the corallum, averages 1 cm. in diameter, and is composed of a series of long intersecting lines, which are the intercepted edges of the tabellae. Short septal crests, usually less than 1 mm. in length, cross portions of the dissepimentarium at certain growth stages. At others they have entirely disappeared. A longitudinal section shows peripheral zones of small, axially convex dissepiments, ranging from 4 to 6 mm. in width; and a central tabularium, averaging 1 cm. in diameter, composed of an ascending series of alternately large and small tabellae, all of which are distally arched.

Remarks: The clear line of demarcation between the tabularium and the the dissepimentarium, which is far more extreme than in any other species of *Mesophyllum* that the author has examined, seems to point to the conclusion that this species is a primitive form not as far advanced in the development of these forms from Cyathophylloid ancestors. The prevalence of crests of degenerate septa in the earlier growth stages of this species bears out this conclusion in the author's opinion.

Horizon and locality: Holotype; Basal 500 feet of the Nevada limestone near the mouth of Frazier Creek, north end of Roberts Mountains, Roberts Mountains quadrangle, Nevada. Paratype; Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94459.

Paratype: U. S. Nat. Mus., 94460.

MESOPHYLLUM LONENSE Stumm, n. sp.

Plate 53, figure 15; plate 55, figure 11

External features: The holotype is a small, curved trochoid coral with the distal end including the calyx missing. The specimen measures 3.5 cm. in length and expands from a pointed base to a diameter of 2.5 cm. at the distal extremity. The exterior is covered by a heavy epitheca on which no vertical striations are visible. Occasional growth expansions at varying distances increase the diameter of the corallum by as much as 5 cm.

Internal features: A transverse section shows a narrow dissepimentarium, usually less than 5 mm. in diameter, composed of relatively small, axially convex dissepiments, on which no septal crests can be determined. The central tabu-

larium averages 1.5 cm. in diameter and is composed of a series of arcuate intersecting lines, representing the cut edges of the tabellae. The dissepiments in the peripheral zone are larger than those in *M. robertsense* and the section does not show the abrupt transition between the dissepimentarium and the large axial tabellae so characteristic of that species. In a longitudinal section of a complete individual, the peripheral dissepimentarium, composed of small, axially inclined dissepiments, expands from a diameter of 2 mm. near the base to almost 1 cm. at the distal end. The tabularium, composed of large cystose tabellae, which are mainly distally convex and inclined proximally at their axial terminations, expands rapidly from the base to a diameter of 1 cm. and remains at the same diameter to the distal extremity.

Remarks: This species has evidently progressed farther in the evolution of the "Cystiphylloid" type. The tabularium and the dissepimentarium are not as clearly distinguished as in *M. robertsense*, there being occasional large dissepiments in the dissepimentarium, which give the appearance of interspersed tabellae. In addition, the lack of septal crests points toward a more advanced stage of Cystiphylloid development, though not nearly as extreme as that shown by *M. vesciculosum*, in which the dissepimentarium is indistinguishable from the tabularium in the transverse section. *M. vesciculosum*, however, does show occasional septal crests in younger growth stages.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus., 94461.

Paratype: U. S. Nat. Mus., 94461*a*.

MESOPHYLLUM FLEXUM Stumm, n. sp.
Plate 55, figure 12

External features: The holotype is the central portion of a large cylindroid coral measuring approximately 10 cm. in length, with an average diameter of 6 mm. The exterior has been so badly weathered that it yields no information regarding the structure of the epitheca.

Internal features: A transverse section shows that the tabularium and dissepimentarium are very irregularly arranged. In places the tabularium extends almost to the periphery; in others, the dissepimentarium extends two-thirds of the distance to the axis. This structure gives the tabularium an irregular outline, with alternate peripheral extensions and axial indentions. The dissepimentarium is composed of small to medium-sized, axially directed dissepiments, on which short septal crests are visible. The tabularium is composed of long, concentric, or irregularly arranged lines, representing the cut edges of the tabellae. A longitudinal section exhibits peripheral zones ranging from 1 mm. to almost 2 mm. in diameter, composed of axially convex dissepiments. The central tabularium, ranging from 2 mm. to almost 4 mm. in diameter, is composed of short tabellae, most of which are strongly distally arched.

Remarks: The irregular outline of the tabularium in this species is a very unusual character that is not represented in any other species of this genus that the author has seen. With the exception of this character the structure is typical of *Mesophyllum*, and more closely approaches that of *M. vesciculosum*, except that the dissepiments are larger and that the tabularium can be distinguished in the transverse section.

Horizon and locality: Basal 500 feet of the Nevada limestone near mouth of Frazier Creek, north side of Roberts Mountains, Roberts Mountains quadrangle, Nevada.

Holotype: U. S. Nat. Mus. 94462.

Genus MESOPHYLLOIDES Wedekind, 1922 (26)

Genotype: By subsequent designation of S. Smith mss. *Mesophylloides richteri* Wedekind (op. cit.).

MESOPHYLLOIDES KIRKI Stumm, n. sp.
Plate 55, figure 13

External features: The holotype is the

central portion of a simple, curved trochoid coral measuring 3 cm. in diameter at the proximal end and expanding to 3.5 cm. in diameter across the distal face in a vertical distance of 3 cm. Weathering has removed the epitheca and has exposed the vertical skeletal elements on the surface of the specimen.

Internal features: In the transverse section a radial series of approximately 80 septa cross the dissepimentarium. These septa are not distinguishable into a major and minor series and are thin and very irregular in shape, joining together or bifurcating in various places. The majority of the septa split longitudinally into a series of lamellae on approaching the periphery, and all of them die out along the border of the tabularium. They range from 0.5 to 1.5 cm. in length. Between the septa are crowded dissepiments, many of which are strongly peripherally arched, and others oblique, or incomplete and abutting against one another. The dissepimentarium ranges from 1 to 1.3 cm. in diameter, and the tabularium, occupying the central portion of the corallum, averages 1 cm. in diameter, and is composed of large tabellae arranged in concentric layers. The longitudinal section shows zones of small, axially directed dissepiments, extending from 1 to 1.2 cm. inward from the periphery. The central tabularium averages 1 cm. in diameter, and consists of a series of small tabellae which are usually distally arched but are occasionally interspersed with horizontal ones.

Remarks: Wedekind established the genus *Mesophylloides* to designate those Cystiphylloid corals in which the septal degeneration had not progressed to as great an extent as in *Mesophyllum*. In *Mesophylloides*, the septa, while degenerate, have not reached the point where they have become separated into the discontinuous crests that characterize *Mesophyllum*. *Mesophylloides kirki*, while definitely related to the species described by Wedekind, has much thinner septa and more strongly developed dissepiments. The species is evidently close to the vague boundary between *Mesophylloides* and *Mesophyllum*. As the great majority of the septa in *Mesophylloides kirki* cross the dissepimentarium without becoming discontinuous, the species appears to belong in *Mesophylloides* rather than in *Mesophyllum*.

Horizon and locality: Basal 500 feet of the Nevada limestone at Lone Mountain, 18 miles northwest of Eureka, Nevada.

Holotype: U. S. Nat. Mus. 94463.

REFERENCES

1. MEEK, F. B., *U. S. Geol. Expl. 40th Par. Rept.*, vol. 4, pt. 1, pp. 25–34, pl. 2, 1877.
2. WALCOTT, C. D., Paleontology of the Eureka district: *U. S. Geol. Survey, Mon.* 8, pp. 100–106, 1884.
3. BILLINGS, E., On some new or little known fossils from the Silurian and Devonian rocks of Ontario: *Canadian Naturalist*, new ser., vol. 7, pp. 230–240, 1874.
4. BILLINGS, E., *Canada Geol. Survey, Summary Rept. for 1857*, p. 176, 1858.
5. O'CONNELL, M., Revision of the genus *Zaphrentis: New York Acad. Sci., Annals*, vol. 23, pp. 177–192, 1914.
6. SOWERBY, J, *Min. Conch.*, T. 1, pp. 165–166, pl. 72, 1812.
7. WEDEKIND, R., Zur Kenntnis der Stringophyllen des oberen Mitteldevon: *Gesell. Förderung gesamt. Naturwiss. Marburg, Sitzungsber.*, pp. 8–13, text figs. 13–14, p. 14, 1922.
8. FENTON, C. L., and FENTON, M. A., The stratigraphy and fauna of the Hackberry stage of the Upper Devonian: *Michigan Univ., Mus. Geology, Contr.*, vol. 1, pp. 30–41, pls. 2–6, 1924.
9. GOLDFUSS, G. A., Petrefacta Germaniae, p. 54, 1826.
10. KING, W., On some families and genera of corals: *Annals and Mag. Nat. History*, ser. 2, vol. 3, p. 388, 1849.
11. LANG, W. D., and SMITH, S., A critical revision of the rugose corals described by W. Lonsdale, in Murchison's "Silurian System": *Geol. Soc. London, Quart. Jour.*, vol. 83, pp. 454–455, 1927.
12. HALL, JAMES, Corals of the upper Helderberg and Hamilton groups: *Illustrations of Devonian fossils*, pl. 22, fig. 6, 1876.
13. LAMBE, LAWRENCE M., *Canada Geol. Survey, Contributions to Canadian paleontology*, vol. 4, pt. 2, pp. 134–137, pl. 10, fig. 6, and pl. 11, fig. 3. 1901.

14. MILNE-EDWARD, HENRI, and HAIME JULES, A monograph of the British fossil corals: *Paleont. Soc.*; p. 425, 1851; p. 242, pl. 56, figs. 2–2e, 1853.
15. SCHLÜTER, C., Über einige Anthozoen des Devon: *Deutsche Geol. Gesell., Zeitschr.* Band 33, pp. 91–99, pls. 9–11, 1881.
16. SIMPSON, G. B. Preliminary descriptions of new genera of Paleozoic rugose corals: *New York State Mus., Bull.*, vol. 8, p. 218, 1900.
17. MILNE-EDWARDS, HENRI, and HAIME, JULES, Monographie des polypiers fossils des terrains palaeozoiques: *Arch. Mus. Nat. Hist. Paris*, 5, p. 387, pl. 12, figs. 1, 1a, 1b, 1851.
18. LANG, W. D., and SMITH, S., *Cyathophyllum caespitosum* Goldfuss, and other Devonian corals considered in a revision of that species: *Geol. Soc. London, Quart. Jour.*, vol. 91, p. 558, 1935.
19. GRABAU, A. W., Stratigraphic relationships of the Tully limestone and the Genesee shale in eastern North America: *Geol. Soc. America, Bull.*, vol. 28, p. 957, 1917.
20. MILNE-EDWARDS, HENRI, and HAIME, JULES, Monographie des polypiers fossiles des terrains palaeozoiques: *Arch. Mus. Nat. Hist. Paris*, 5, pp. 447–448, pl. 10, fig. 5, 1851.
21. CALVIN, S., Notes on some of the fossil corals described by David Dale Owen . . . : *Am. Geologist*, vol. 12, no. 2, pp. 111, 112, pl. 6, 1893.
22. HALL, JAMES, Corals of the upper Helderberg and Hamilton groups: *Illustrations of Devonian fossils*, pl. 27, 1876.
23. SCHLÜTER, C., Anthozoen des Rheinischen Mitteldevon: *Abh. geol. Specialkarte Preussen und den Thüringischen Staaten*, vol. 8, pt. 4, pp. 75, 76, pl. 7, fig. 2, 1889.
24. WEDEKIND, R., Das Mitteldevon der Eifel: *Gesell. Förderung gesamt. Naturwiss. Marburg, Schrift.*, vol. 14, pp. 38, 39, 1925.
25. GOLDFUSS, G. A., *Petrefacta Germaniae*, p. 58, pl. 17, fig. 5e, 1826.
26. WEDEKIND, R., Beiträge zur Kenntnis der Mesophyllen: *Paleont. Zeitschr.*, vol. 4, pp. 48–63, 1922.

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THE GENUS *CYNARCTUS*

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ABSTRACT

The genus *Cynarctus*, represented by three Miocene and one lower Pliocene species, which was formerly supposed to be intermediate between the dogs and the bears, is proved by new finds of *C. acridens* to be a relatively large doglike raccoon, an aberrant branch of the Procyonidae.

The genus *Cynarctus* was described by Matthew (1902), who based it upon *Cynarctus saxitilis*, the holotype of which is a pair of well-preserved lower jaws from the Pawnee Creek (middle Miocene) of Colorado. *Cynarctus acridens* and *Cynarctus crucidens* were described by Barbour and Cook (1914). The former was based upon a small portion of jaw containing $M_{\overline{1}}$, from the upper Harrison beds (lower Miocene) of western Nebraska and the latter upon a well-preserved lower jaw from the lower Pliocene of Brown County, Nebraska. In 1932 Matthew described *Cynarctus mustelinus* on two partial lower jaws from the middle Miocene Sheep Creek beds of western Nebraska. At present our entire knowledge of the genus comes from the characters of these four species, all based upon lower jaws.

In the summer of 1936 the writer obtained a lower jaw from the upper Harrison beds of western Nebraska which is referable to *Cynarctus acridens*. The discovery of this new specimen makes it possible to determine more fully the characters of this species and, owing to its ancestral position, to arrive at some definite conclusions concerning the relationships of the genus.

SYSTEMATIC DESCRIPTIONS

Family PROCYONIDAE Bonaparte

New subfamily CYNARCTINAE

Genus CYNARCTUS Matthew, 1902

Generic characters: Dental formula $I\frac{3}{3}C\frac{1}{1}P\frac{4}{4}M\frac{3}{3}$; $P_{\overline{4}}$ with internal accessory cusp in advanced species; $M_{\overline{1}}$ with cusp external to protoconid and an accessory cusp posterior to metaconid; trigonid of $M_{\overline{1}}$ low and talonid relatively high; $M_{\overline{2}}$ with cusp external to protoconid and an accessory cusp posterior to metaconid; $M_{\overline{3}}$ small in primitive species and relatively large in advanced species; jaw slender.

Genotype: *Cynarctus saxitilis* MATTHEW, *1902*. Am. Mus. Nat. History, Bull., vol. 16, pp. 281–284. Genoholotype: Am. Mus. Nat. History, 9453. A nearly perfect pair of lower jaws.

Horizon and locality: Pawnee Creek beds (middle Miocene), northeastern Colorado.

CYNARCTUS ACRIDENS Barbour and Cook, 1914

Figure 1

Cynarctus acridens BARBOUR and COOK, *1914*, Nebraska Geol. Survey, vol. 4, pp. 226, 227.

Emended specific diagnosis: Small, $P_{\overline{3}}$–$M_{\overline{3}}$ incl. = 53 mm., greatest depth of ramus under trigonid of $M_{\overline{2}}$ = 7.5 mm.;

posterior cinguli of premolars weak; no inner accessory cusp on $P_{\overline{4}}$; cusp external to protoconid of $M_{\overline{1}}$ relatively strong and distinct, accessory cusp posterior to metaconid small and indistinct; $M_{\overline{3}}$ reduced; posterior border of coronoid deeply concave.

The ramus of *Cynarctus acridens* is very slender. The coronoid process rises immediately behind $M_{\overline{3}}$, making an angle of about 90° with a line projected along the alveolar border. The anterior border of the coronoid process, instead of rising with only slight convexity as in *Cynarctus saxitilis*, turns well back as it does in *Procyon*. The posterior border of the coronoid process is highly convex between its tip and the condyle. The condyle is relatively smaller than in *Cynarctus saxitilis*. The angular process is long, nonrugose and very slender, terminating in a rather sharp point, and in general is much like that of *Pseudocynodictis*. The masseteric fossa is deep and extends rather far forward, not restricted anteriorly as it is in *Cynarctus saxitilis*.

$P_{\overline{3}}$ is laterally compressed and has a prominent anterior and relatively small posterior accessory cusp. It has a very weak posterior cingulum, differing in this respect from *Cynarctus saxitilis* and *Cynarctus crucidens*, in which the posterior cinguli are heavy and broad.

$P_{\overline{4}}$ is much like $P_{\overline{3}}$, but the posterior accessory cusp is shifted labially. The posterior cingulum is weak.

$M_{\overline{1}}$ is essentially like that of *Cynarctus saxitilis*, but the cusp that lies external to the protoconid is more prominent and somewhat more distinct from the protoconid. The accessory cusp, which is posterior to the metaconid, is incipient but definitely discernible. The trigonid is lower than that of *Pseudocynodictis*, and the talonid is somewhat more elevated, approaching in this respect the condition seen in the living genera of Procyonidae.

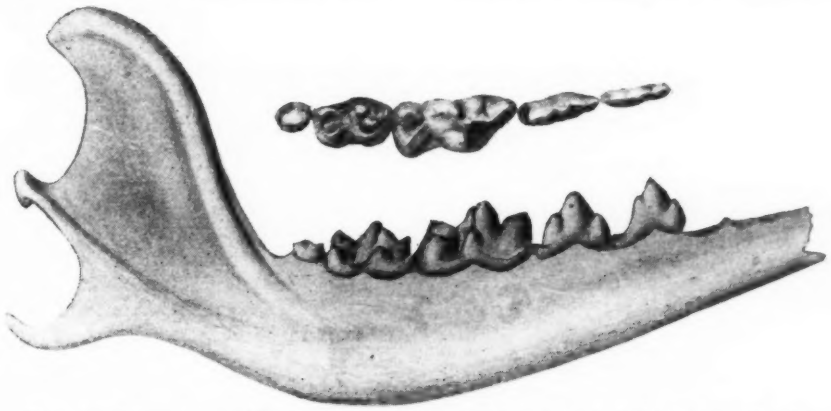

FIG. 1—*Cynarctus acridens*, ref. spec., Univ. Chicago 1547. Labial view of right mandible and occlusal view of lower cheek teeth, ×2.

The talonid is not so broad as that of *Cynarctus saxitilis* but broader than that of *Pseudocynodictis*. The hypoconid and entoconid are relatively high rounded cusps, the latter nearly equalling the metaconid in height and the former much lower. An anterior extension of the entoconid reaches forward to meet the posterointernal accessory cusp of the trigonid. A low ridge runs obliquely across the talonid from the hypoconid to the metaconid. A rather strong external cingulum runs between the talonid and the trigonid, and a cingulum is present beneath the shearing portion of the trigonid.

$M_{\overline{2}}$ is surprisingly like $M_{\overline{1}}$. It shows a well-developed trigonid with a strong metaconid, a less prominent protoconid, and a weak but distinct paraconid.

A strong, blunt accessory cusp is developed external to the protoconid, and a small incipient cusp lies behind the metaconid. In the only known specimen of the genotype these cusps are practically worn away but appear to have the same general relationships. The talonid is like that of $M_{\overline{1}}$, having a prominent entoconid and lower hypoconid.

$M_{\overline{3}}$ is reduced and nearly round, with weak unidentifiable cusps around a shallow basin. This tooth is heavily worn in the types of both *Cynarctus saxitilis* and *Cynarctus crucidens*, but in both a well developed cuspate heel is apparent.

Holotype: H. C. 144, collection of Harold J. Cook; a portion of a right lower jaw containing $M_{\overline{1}}$.

Horizon and locality: Upper Harrison beds (lower Miocene), 4 miles northeast of Agate, Sioux County, Nebraska.

Referred specimen: University of Chicago, 1547, from upper Harrison beds east of Agate, Sioux County, Nebraska. Right lower jaw.

RELATIONSHIPS OF CYNARCTUS

Misconceptions have arisen concerning the phyletic relationships of *Cynarctus* because it has previously been well known only from end forms.

Matthew (1902) regarded the genus as intermediate between the Canidae and the bears. He felt that its characters linked *Ursavus* (from upper Miocene of Europe) with *Canis*. He said:

> If this be borne out by the characters of the upper teeth, *Cynarctus* will help to bridge the most serious gap in the series of extinct genera connecting the Ursidae and the Canidae.

He considered *Cynarctus* as a branch of the canid stock, which, while not directly ancestral, was near the direct line of descent to the bears.

Gregory (1910) stated:

> . . . the pattern of the post-canine lower teeth of *Phoca cichigensis* Allen (1902) might readily be derived from those of the curious amphicyonine canid *Cynarctus saxitilis* Matthew.

Barbour and Cook regarded *Cynarctus* as

> . . . representative of a line of Canidae, which branched off from the root stock not later than early Oligocene, and more closely parallels the typical contemporary dogs than the Ursidae, to which they show affinities.

They also noted

> that the resemblance in the latter forms of *Cynarctus* to the primitive bears may be, to a large degree, analogous development rather than true homology.

That *Cynarctus* represents a branch of the Procyonidae is a view that has not been suggested by previous writers, yet close comparison of the dental and mandibular characters of material now available makes any other view untenable. The unquestionable relationships of *Cynarctus acridens* to the advanced species of the genus and its intermediate position between *Bassariscus* and *Phlaocyon* proves the status of the *Cynarctus* line of descent to be that of an aberrant line of the Procyonidae. Apparently *Cynarctus*, like *Bassariscus*, lived on after giving rise to a more successful and progressive group. Unlike *Bassariscus*, however, *Cynarctus* diverged rather widely from its ancestral stock and developed unique adaptations, combining certain characters of the Canidae with those of the Procyonidae, which resulted in a relatively large, doglike racoon.

The characters of *Cynarctus acridens* that indicate its procyonid affinities may be brought out by a direct comparison with *Procyon*.

General mandibular characters: The jaw of *Cynarctus acridens* is similar in form to that of *Procyon*. The curvature of the former is only slightly less pronounced than that of the latter, and the area of greatest convexity of the lower border in both is under $M_{\overline{3}}$. A striking resemblance is noted in the ascending ramus of *Procyon* and *Cynarctus acridens*. The coronoid of the former rises more anteriorly than that of the latter, owing to the loss of $M_{\overline{3}}$ in *Procyon*. The gently curving anterior border of the coronoid and the concave posterior border are characteristic of both. The distance between the condyle and the angular

process is greater in *Cynarctus acridens*—a primitive condition. The rugosities of the angular area of *Procyon* are wanting in *Cynarctus acridens*, but this again recalls the condition of *Pseudocynodictis* and must be regarded as a primitive character.

Premolars: $P_{\overline{3}}$ is less reduced than that of *Procyon* but more than that of *Pseudocynodictis*. The anterior accessory cusp is retained in the primitive *Cynarctus acridens* and lost in *Procyon*. $P_{\overline{4}}$ of *Cynarctus acridens* has the posterior accessory cusp shifted exteriorly, as in *Procyon*, a step in the molarization of this tooth. The posterior cingulum is but little more developed than in *Pseudocynodictis*, but it is less trenchant. The inner accessory cusp of $P_{\overline{4}}$, seen in *Procyon*, is not developed in *Cynarctus acridens*.

Molars: It is in the molars that the definite procyonid characters of *Cynarctus acridens* are apparent. The most conspicuous trend of this species toward *Procyon* is probably the strong development of the talonid. The cusp external to the protoconid is more posteriorly situated in *Procyon*, but it is very probably homologous with that of *Cynarctus acridens*. Primitively, the outer border of the talonid of *Cynarctus acridens* runs obliquely across to the middle of the posterior edge of the trigonid, whereas in *Procyon* it runs forward to meet the extra cusp, a condition readily derivable from that of the former species. The rounding of the principal cusps, the partial loss of the sectorial function, and the lowering of the trigonid of $M_{\overline{1}}$ all indicate that structurally *Cynarctus acridens* is not far off the direct line to *Phlaocyon* and *Procyon*.

The parallel development of $M_{\overline{2}}$ to $M_{\overline{1}}$ is also indicative of procyonid affinities, for in *Procyon* the two teeth are of nearly equal size and importance.

This combination of characters, primitive ones of the Canidae combined with progressive ones of the Procyonidae, seems sufficient to firmly establish *Cynarctus* as a Procyonid, more progressive than *Bassariscus* and less so than *Phlaocyon*. Most of these primitive characters are retained in the Miocene-Pliocene species of *Cynarctus*, and this serves as another striking example of the survival of a genus possessing ancestral characters to a later period when it is a contemporary of its more specialized descendants. The condition in this case is paralleled in the horses by *Hypohippus*, which retained a primitive tooth pattern but became modified in other particulars.

On the evidence afforded by the characters of *Cynarctus acridens*, a more detailed phylogeny (fig. 2) may be erected, which shows more clearly the steps in the origin of the subfamily Procyoninae.

Although *Bassariscus* has been found in deposits no earlier than upper Miocene it may reasonably be assumed that the form has not changed appreciably since it departed from the canid stock, probably in the Oligocene. It is very probable, therefore, that future work will reveal its presence in Oligocene deposits of western America. *Cynarctus acridens* is but a step from *Bassariscus* in the direction of *Phlaocyon* and seemingly represents a very early form of a line that diverged from *Bassariscus* in latest Oligocene time. This *Cynarctus* line of descent survived at least until the early Pliocene, then apparently became extinct. *Cynarctus saxitilis* and *Cynarctus crucidens* seem to represent nearly similar stages of progressive development—a fact that is surprising if the former is a middle Miocene species. Since lower Pliocene horizons occur in the Pawnee Creek area it is conceivable that the holotype of *Cynarctus saxitilis* may have come from the lower Pliocene. If, in reality, the species is from the middle Miocene there must have been extremely rapid progression in this line of descent between early and middle Miocene.

The notable reduction of $M_{\overline{3}}$ in *Cynarctus acridens* might indicate a closer relationship of this species to the Procyoninae than to the true *Cynarctus* line, the Cynarctinae. It is probable, however, that the development of this tooth was

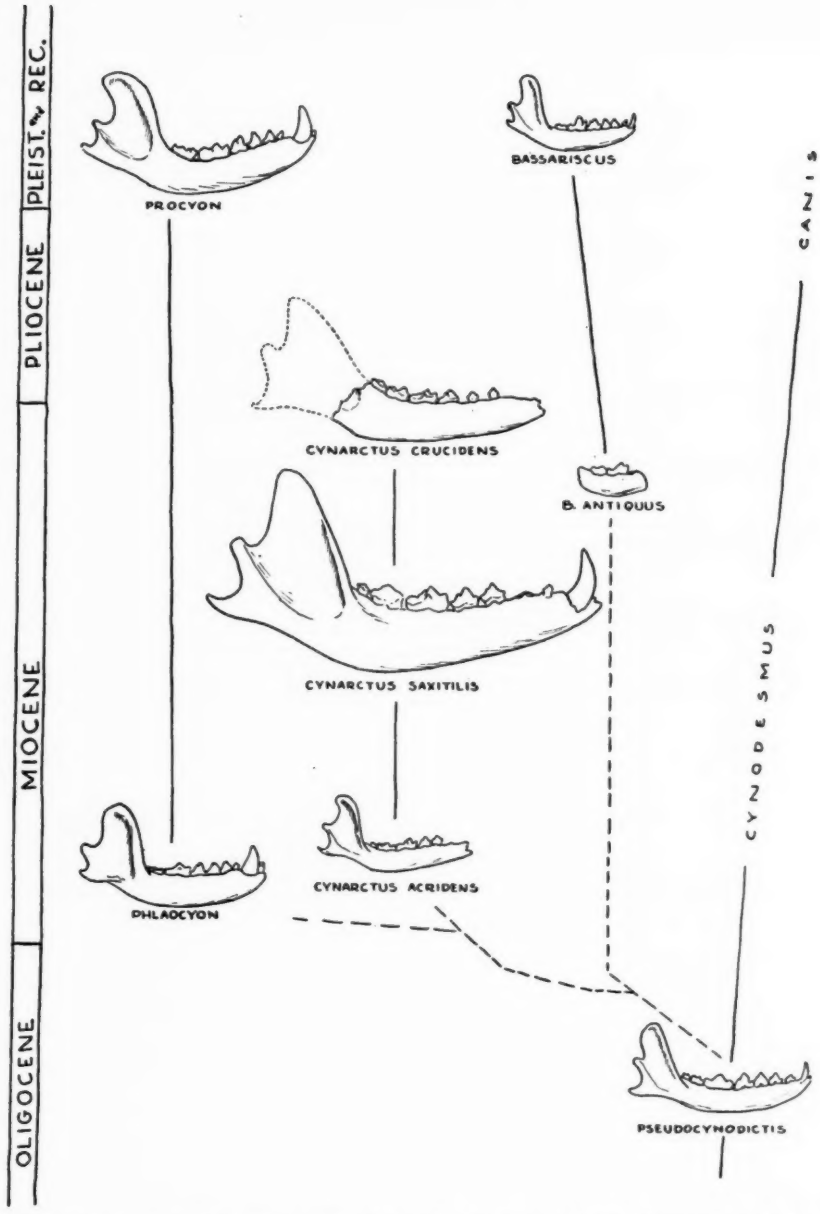

FIG. 2—The phylogeny of the Procyonidae showing the probable phylogenetic relationships of the Bassariscinae, the Cynarctinae, and the Procyoninae.

secondarily accelerated, for it is larger and more cuspate in the advanced species of *Cynarctus*.

Matthew was of the opinion that *Nothocyon* represented the canid genus from which the Procyonidae diverged (1899) and recognized *Cynarctus acridens* as a species intermediate between the advanced species of *Cynarctus* and *Nothocyon* (1932). It is very possible that *Nothocyon* does occupy this position, but more evidence must be obtained before it can be regarded as established.

Phlaocyon (Wortman and Matthew, 1899), which is approximately ancestral to *Procyon*, was contemporaneous with *Cynarctus acridens* and probably represents a line that originated from *Cynarctus* in earliest Miocene time. *Aletocyon* (Romer and Sutton, 1927) differs from *Phlaocyon* slightly in proportion and in the peculiar encroachment of the paroccipital process upon the tympanic bulla. Whether or not these differences are sufficient to warrant generic separation is questionable. The suggested ancestral position of *Aletocyon* to *Ailurus* seems justified, as the characters of the former are sufficiently primitive for both *Ailurus* and *Procyon* (and probably certain other living procyonids) to have been derived from it.

The position of many of the living genera of Procyonidae in relation to the known fossil forms is extremely hard to postulate. *Ailuropus*, with its highly specialized dentition, may have been derived from some early form close to *Cynarctus*, which would account for the presence of $M\frac{3}{3}$ in the Giant Panda. As Gregory (1936) has pointed out, the other plausible explanation for the presence of this tooth is that

> . . . great growth energy at the posterior end of the dental lamina has caused the splitting off of a new dental papilla, which would be as much a neomorph as are the occasional supernumerary posterior molars ($M\frac{4}{4}$) of anthropoid apes and man.

The inclusion of *Cynarctus* in the Procyonidae lends favor to the former view, that the presence of $M\frac{3}{3}$ in *Ailuropus* is a paleotelic character.

Bassaricyon, *Nasua*, and *Potos* were obviously derived from some early ancestral procyonid, but at what stage they made their departure from the known lines of descent cannot be determined at present. *Euprocyon* is closely related to *Procyon* and is probably of relatively recent origin.

I wish to express my thanks to the following persons and institutions for facilitating my study of *Cynarctus:* Dr. Walter Granger and The American Museum of Natural History for allowing me to study the type of *Cynarctus saxitilis*, Dr. E. H. Barbour, of the University of Nebraska, for sending me a cast of the type of *Cynarctus crucidens*, and Mr. Bryan Patterson and the Field Museum of Natural History for making available their collections for study.

REFERENCES

1. Barbour, E. H. and Cook, Harold J., Two new fossil dogs of the genus *Cynarctus* from Nebraska: *Nebraska Geol. Survey*, vol. 4, pt. 15, pp. 225–227, 1914.
2. Gregory, W. K., The orders of mammals: *Am. Mus. Nat. History, Bull.*, vol. 27, pp. 1–524, 1910.
3. Gregory, W. K., On the phylogenetic relationships of the Giant Panda (Ailuropoda) to other arctoid carnivora: *Am. Mus. Novitates*, no. 878, pp. 1–29, 1936.
4. Matthew, W. D., New Canidae from the Miocene of Colorado: *Am. Mus. Nat. History, Bull.*, vol. 16, art. 21, pp. 281–290, 1902.
5. Matthew, W. D., New fossil mammals from the Snake Creek quarries: *Am. Mus. Novitates*, no. 540, pp. 1–8, 1932.
6. Romer, A. S., and Sutton, A. H., A new arctoid carnivore from the lower Miocene: *Am. Jour. Sci.*, vol. 14, no 84, pp. 459–464, 1927.
7. Wortman, J. L. and Matthew, W. D., The ancestry of certain members of the Canidae, the Viveridae, and the Procyonidae: *Am. Mus. Nat. History, Bull.*, vol. 12, art. 6, pp. 109–138, 1899.

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EUCERATHERIUM BIZZELLI, A NEW UNGULATE FROM OKLAHOMA

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ABSTRACT

An almost perfect occiput, skull crown, and horn cores of a new ungulate found in reworked Pleistocene gravel at Hydro, Oklahoma, are described and figured as *Euceratherium bizzelli*. The genus ranged across North America between Iowa and Oklahoma.

In the spring of 1936 while removing sand and gravel from a pit at Hydro, Caddo County, Oklahoma, Mr. John Kaufman of Norman, Oklahoma, discovered an exceptionally well preserved fragment of a very unusual skull representing a new *Euceratherium*, which he was kind enough to donate to the Museum of Geology and Paleontology of the University of Oklahoma.

The pit in which this specimen was found is in high-level reworked river gravel about 100 feet above the level of the Canadian River, which is the lowest stream in the area. Associated with it were fragments of proboscideans, equids and bovids.

The geological age of the animal is unquestionably Pleistocene, and judging by the lack of replacement of the bone, probably late Pleistocene. If such is the case, it corresponds with the assigned age of the California material described by Sinclair and Furlong (7). Because of the uncertainty of dating reworked deposits, however, it is possible that it belongs to an earlier division of the Pleistocene. These high-level gravels are similar in their stratigraphic relationship and topographic position to a deposit 60 miles to the west in which an articulated *Procamelus*, a Pliocene camel, was found. The camel bones were *in situ* and completely replaced, probably indicating a much longer time of burial.

No small part of the importance of the discovery at Hydro lies in the fact that the range of *Euceratherium* is shown to extend from Iowa to Oklahoma and to California. The actual distribution was doubtless much farther north than Missouri Valley, Iowa, and farther south than Hydro, Oklahoma. If the extinct American "eland," *Taurotragus americanus* Gidley (4), from Cumberland Cave, Maryland, is in reality *Euceratherium* as suggested by Gazin (3), the range of the genus covered not only the central region of North America but extended from the Pacific to the Atlantic Ocean. The discovery of *Preptoceras mayfieldi* Troxell (9) at Rock Creek, Texas, suggests that these two forms may have been plains dwellers.

EUCERATHERIUM Sinclair and Furlong

Generic characters: In stating the generic characters, the writer cannot do better than to quote that part of the

original description which is applicable to the specimen under consideration. "Horn-cores solid, situated close together . . . Frontals reaching to occiput, with strongly developed pneumatic cavities extending into the base of the horn-cores. Parietal confined to occiput, forming no part of the cranial roof . . ." (7, p. 412).

EUCERATHERIUM BIZZELLI, n. sp.
Figures 1–3

Diagnosis: Horn cores well in advance of the posterior extremity of the skull. No inflation of the frontals at base of horn cores. A slight ridge at the median suture of the frontals. Lambdoidal crest not overhanging.

Holotype: Museum of Geology and Paleontology, Univ. Oklahoma, 701.

The specific name is given in honor of Dr. William Bennett Bizzell, President of the University of Oklahoma, who has always actively encouraged those engaged in the advancement of natural science.

Description: The specimen consists of the crown of the skull from the posterior margin of the left orbit backward to and including the occipital condyles and basisphenoid. The occiput is preserved in fine detail and completeness. About three-quarters of an inch of the tip of each horn core and some of the ends of a few of the processes on the posterior part of the base of the skull have been broken off. The facial part of the skull, the teeth, and the mandibles are, unfortunately, missing. An animal of considerable size is indicated, for the occipital condyles are 103 mm. in width. The total width of the skull just above the foramen magnum is slightly greater than in the average Hereford cow 3 years old. The diploë, as pointed out by Sinclair and Furlong, are large and well developed. The bone forming the roof of the skull anterior to the horns is thin. Only the posterior third of the left orbit is present; this fragment would indicate only moderately prominent orbital rims. The suture between the frontals forms a slight ridge, which terminates 30 mm. in front of the horn cores. Behind this ridge the skull is slightly depressed, the two outer margins lacking the inflation seen at the base of the horn cores of *E. collinum* (7, p. 413). The thoroughly ankylosed condition of the sutures indicates a mature animal.

When the skull is held in normal position, as seen in fig. 2, the horn cores rise

FIG. 1—*Euceratherium bizzelli* Stovall, n. sp. Front view showing horn curvature and nutrient grooves. Width outside of horn cores 539 mm.

from the frontals in such a manner that their anterior margins are almost immediately above the posterior margins of the orbits, from which they are separated by a space of 52 mm. The cranium is constricted laterally beneath the horn cores so that their total diameter is 29 mm. greater than the diameter of the skull just beneath them, as is shown in fig. 3. In the region between the cores, the bone of the horn core grades almost imperceptibly into that of the cranium. Obviously, no burr is present, but the anterior and the ventral part of the base of the horn core is somewhat larger in circumference than the bone on which they rest, as shown by fig. 1. Nutrient grooves and foramen are conspicuous at the base of the cores, particularly on the posterior margin (see figs. 1, 2, and 3). The basal one-sixth of the cores have several grooves paralleling the long axis and measuring from 1 to 3 mm. in depth and as much as 83 mm. in length. On the ventral side of each core and lying in the upper arch of the horn there is an elongate sulcus about 10 mm. wide, 4 mm. deep, and about 175 mm. long. These features are slightly different in the two cores, the one in the right approaching somewhat closer to the distal end. Toward the upper edge of the anterior side of the left core there is a broad, shallow sulcus, which is only faintly suggested in the right core. The frontals form a pronounced valley between the bases of the horn cores, which are very close together.

The sutures between many of the bones have been so completely ankylosed that it is difficult to trace them. Indeed, some of the sutures cannot be traced at all. Between the posterior margins of the horns there is a very shallow and somewhat heart-shaped depression in the frontals. The frontals extend backward to the lambdoidal crest, which turns sharply into the occiput. The occiput is roughly concave, and the lambdoidal crest does not overhang this region; but there is a well-developed median occipital tubercle formed by the downward extension of the frontal and the parietals, on either side of which is a slight suggestion of a fossa. Beneath the median tubercle and connected to it is a sharp ridge about 3 mm. high extending to a point within 10 mm. of the foramen magnum. There is no ridge from the lambdoidal crest to the base of the horns, nor is there a concavity between the lambdoidal crest and the horn cores. The paroccipital processes are robust and long. The basisphenoid is roughly triangular, but it has a deep sulcus in its posterior third, which grows shallower and narrower anteriorly. The tympanic bullae are laterally compressed and lie almost wholly below the postglenoid processes. The median tubercle of the bulla is conical and well-developed.

Comparisons: At first glance the resemblance of *E. bizzelli* to *Ovis canadensis* is striking, but the resemblance is only superficial, for the horns point forward (a character also found in *Preptoceras*) instead of backward. Again at first glance, this skull resembles the figures of *Preptoceras sinclairi* (2) more closely than it does the figures of *Euceratherium* (7, pls. 50, 51) as given in the papers on the type specimens. However, Furlong and Sinclair's description, and horn cores of *Euceratherium* and of *Preptoceras* loaned to the writer by Charles L. Camp and R. A. Stirton, of the University of California, Museum of Paleontology, show clearly that if these two forms represent valid genera, *bizzelli* must be referred to *Euceratherium*.

The shape, size, curvature, and nutrient grooves of the horn core of the Oklahoma specimen indicate that it is referable to the form described as *Euceratherium* by Sinclair and Furlong (7, p. 412). Horn cores of the form described as *Preptoceras*, loaned to the writer by Camp and Stirton, are almost perfectly round at the base, but in *bizzelli* the horn cores are markedly compressed in that region. The greater diameter of the horn core of the new species exceeds that of *E. collinum* by 23 mm., and its smaller diameter is 22 mm. greater—a character

probably due to difference in age of the two animals, for the horn cores of the California specimen are almost identical in size, curvature and shape with those of this individual. Even the longitudinal grooves correspond very closely.

Comparison of *E. bizzelli* with *Aftonius calvini* Hay (5) as figured by Hay (6) and Calvin (1) also reveals several similarities. The curvature of the basal half (the only part of the core preserved in "*Aftonius*" *calvini*) and the cross-sectional shape of the two species are almost identical. The grooves and foramen occupy the same position around the base of the cores, and are equally well developed in both species. The chief difference between these two sets of cores, excepting the fact that the Hay specimen is less complete, is in size; the horn cores of *E. bizzelli* are 24 mm. larger than the greater diameter and 8 mm. greater than the shorter diameter of "*Aftonius*" *calvini*. This slight disparity is easily explained on the basis of sex or age differences. The writer therefore concludes that *Euceratherium* and *Aftonius* are identical. If these conclusions are correct, *Euceratherium* must take precedence; and, henceforth, *Aftonius* should be included in that genus.

A summation of the characters of *Euceratherium* indicates that it might be placed in either of the subfamilies Ovinae or Ovibovinae; for while it has certain affinities that apparently ally it with the Ovinae, it has other characters that appear to relate it just as closely to the Ovibovinae. However, these characters may indicate family and not subfamily affinities. The omission of the parietal from the roof of the cranium, and other features possessed by *Euceratherium* and *Preptoceras* might indeed be sufficient to warrant placing these two forms in a new subfamily. It seems advisable at present not to attempt a definite conclusion concerning the subfamily to

FIG. 2—*Euceratherium bizzelli* Stovall, n. sp. Lateral view showing forward projection of horn cores. Height 292 mm.

which the genus belongs until more material is available for comparison.

Stock and Furlong (8, p. 427) have suggested that *Euceratherium* and *Preptoceras* might properly be referable to one genus and that the differences may be explained as sex dimorphism. In order to be at all certain that these differences are sexual, it is necessary to show that similar differences prevail between the sexes of living species. Although the writer has not had an opportunity to study all of the California specimens, an examination of the horn cores borrowed from Camp and Stirton and a comparison of them with the Oklahoma specimen would indicate generic and not sex differences as suggested by Stock and Furlong. Sex differences in horn cores are usually largely a matter of size. For example, the horn cores of the female of *Bos* have a smaller cross-sectional diameter than

Summation of Characters

Ovibovinae	Ovinae	*Euceratherium*
Frontal not reaching occiput.	Frontal not reaching occiput.	Frontal reaching occiput.
Parietal paired. Horns project laterally.	Parietal unpaired. Horns rise at a sharp angle.	Parietal unpaired. Horns rise at a sharp angle.
Horns rise from margin of cranium.	Horns rise from near center of cranium	Horns rise from near center of cranium
Dentition similar in all, but *Euceratherium* appears to be closer to the Ovibovinae.		
The cannon bones appear to indicate relationship to the Ovibovinae.		
General appearance of the skull is sheeplike (8, p. 426).		
The ratio of the horn size to skull size is more like the Ovibovinae.		

FIG. 3—*Euceratherium bizzelli* Stovall, n. sp. Posterior view showing occiput. Width of occiput 155 mm.

those of the male. The same thing may be said of *Bison*. Assuming that *Bos* and *Bison* are distinct genera, their horn cores are much more alike than the horn cores of *Euceratherium* and *Preptoceras*. In these two forms, the great difference in cross-sectional shape in the proximal third of the core and in their curvature argue very strongly for two genera.

MEASUREMENTS

	mm.
Maximum spread of horns	539
Width between superior orbital rims	170
Width across base of horn cores	143
Greatest diameter of horn cores	99
Smallest diameter of horn cores at base	65
Greatest width of occiput	155
Distance between occipital tubercle and foramen magnum	48
Width of cranium between horn cores and lambdoidal crest	103
Distance between horn cores one inch above notch in frontal	46
Transverse width of occipital condyles	103
Vertical thickness of occipital condyles	40
Length of left horn core from base to broken end, 548 plus about 26 mm. for broken part	574

Acknowledgments—Thanks are extended to Messrs. O'Reilly Sandoz and Ralph Shead for the drawings accompanying this paper. Appreciation is expressed to Mr. John Kaufman for donating the specimen to the University, to Prof. Charles L. Camp and Prof. R. A. Stirton for the loan of horn cores of *Euceratherium* and *Preptoceras*, to Mr. Bryan Patterson for a kindly criticism of this manuscript, and to Prof. A. K. Miller for the loan of the type "*Aftonius*" *calvani* Hay from Cox Pit, Missouri Valley, Iowa.

REFERENCES

1. Calvin, Samuel, Aftonian mammalian fauna: *Geol. Soc. Am., Bull.*, vol. 20, p. 350, pl. 23, fig. 1, 1909.
2. Furlong, Eustace L., *Preptoceras*, A new ungulate from the Samuel Cave, California: *Calif. Univ., Dept. Geol. Sci., Bull.*, vol. 4, no. 8, pls. 24, 25, 1905.
3. Gazin, C. Lewis, The status of the extinct American "eland": *Jour. Mammalogy*, vol. 14, no. 2, pp. 162–164, May 1933.
4. Gidley, J. W., An extinct American eland: *Smithsonian Misc. Coll.*, vol. 60, no. 27, pp. 1–3, 1913.
5. Hay, Oliver P., Descriptions of two new species of ruminants from the Pleistocene of Iowa: *Washington Biol. Soc. Proc.*, vol. 26, pp. 5–7, 1913.
6. ——— The Pleistocene mammals of Iowa: *Iowa Geol. Survey, Ann. Rept.*, vol. 23, p. 287, pl. 34, figs. 4–5, 1914.
7. Sinclair, William J., and Furlong, Eustace L., *Euceratherium*, a new ungulate from the Quaternary caves of California: *Calif. Univ., Dept. Geol. Sci., Bull.*, vol. 3, no. 20, 1904.
8. Stock, Chester, and Furlong, Eustace L., Skull and skeletal remains of a ruminant of the *Preptoceras-Euceratherium* group: *Calif. Univ., Dept. Geol. Sci., Bull.*, vol. 16, no. 10, 1937.
9. Troxell, E. L., A fossil ruminant from Rock Creek, Texas, *Preptoceras mayfieldi*, sp. nov.: *Am. Jour. Sci.*, 4th ser., vol. 40, pp. 479–482, 1915.

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PALEONTOLOGICAL NOTES

THE GENOTYPE OF *MORTONICERAS* MEEK

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When the genus *Mortoniceras* was described by Meek (1) he designated as the type species *Ammonites vespertinus* Morton (=*A. texanus Roemer*),* adding in a footnote: "*Mr. Gabb, who has compared specimens of *A. texanus Roemer*, from the same locality as Morton's original type of his *A. vespertinus*, says that they are in all respects identical, Morton's figure being very defective."

The essential parts of the original generic description are as follows:

> Shell discoid; periphery with a simple, low, central keel, and a more or less defined sulcus on each side of it; the sulci being generally each margined externally by a row of compressed nodes; umbilicus wide; volutions narrow, slightly embracing, and ornamented by regular, simple, straight, tuberculated costae. Septa in the typical species with three lateral lobes on each side, the first one being longer than the siphonal lobe, with tripartite extremity, the terminal division being deeply bifid; second and third lobes much smaller and more or less tripartite or dentate; first and second lateral sinuses more or less nearly equally bipartite or bilobate at the ends. . . .
>
> . . . It will include, in addition to the type species *T. vespertinus* (=*A. texanus*), one, if not both, of the species hereinafter referred provisionally to it; also, perhaps, *Ammonites leonensis* Conrad; and possibly an East Indian form, referred by Dr. Stoliczka to *A. inflatus* Sowerby, as well as some other Cretaceous species. It seems to be confined to the Cretaceous system.

The only other species definitely referred to the genus is *Mortoniceras shoshonense* Meek, in describing which Meek (1*a*) remarks:

> At one time I was rather inclined to regard it as a variety of *M. vespertinus* Morton; but as the costae in that species seem to be very constant in the possession of four nodes each, while on the form here described each rib is merely represented by two nodes, and these of different forms, I cannot believe it the same species.

In this connection it should be noted that Roemer described *A. texanus* as having five nodes on each rib, but Meek in his generic description treated separately the outer row of compressed nodes at the margin of the sulcus and did not count them as belonging on the ribs. This explains his statement that "the costae in that species [meaning *A. texanus*] seem to be very constant in the possession of four nodes each."

From the foregoing it seems to me self evident that the genotype of *Mortoniceras* as designated by Meek is *Ammonites texanus* Roemer and that although he applied to it the earlier specific name *Ammonites vespertinus* Morton, because Gabb had assured him that the two names were synonyms, he was careful to indicate clearly the species he wished to designate by twice reiterating "=*A. texanus* Roemer," besides mentioning specific features that were characteristic of Roemer's species.

Mortoniceras texanum (Roemer) is an Upper Cretaceous (Senonian) form common in the Austin Chalk of Texas. *Mortoniceras shoshonense* Meek, the only other species positively assigned to *Mortoniceras* by Meek in connection with the original description of the genus, is found in approximately equivalent rocks of Niobrara age in the upper part of the Colorado group in Wyoming.

It may be of service to quote in full Morton's (2) description of *Ammonites vespertinus:*

> *Specific character.* Volutions uncertain; each whorl furnished with profoundly elevated transverse ridges, with three slight nodes on each; that on the margin most prominent.
>
> Length of the fragment, 13½ inches.
>
> My friend Dr. Z. Pitcher, of the United States Army, has presented me with several large fragments of this ammonite from the plains of Kiamesha, in Arkansaw, where it is

accompanied by *Gryphaea vomer*, *G. pitcheri* and *Exogyra costata*. It is allied to *A. delawarensis* but differs in the absence of bifurcations in the costae.

The obviously inaccurate illustration is an oblique view of about half of a volution so posed that the keel (not mentioned in the description) is concealed and a large part of the impressed zone formed by contact with the preceding volution is shown. The figure is reduced to about 61 percent of the actual dimensions.

On present-day maps the locality is in southeastern Oklahoma, and the accepted spelling of the geographic name is Kiamichi.

It is difficult to understand why Gabb identified ammonites from the Kiamichi area with *Ammonites texanus* Roemer. Most probably he had never seen authentic specimens of Roemer's species, and he could not have known that rocks yielding *A. vespertinus* are considerably older than those from which *A. texanus* was obtained. The Cretaceous stratigraphy of the Texas region was greatly confused and misunderstood until the true stratigraphic succession was established by the field work of R. T. Hill and his successors beginning about 50 years ago. It is now well known that *A. vespertinus* came from Lower Cretaceous (Albian) rocks low in the Washita group, probably in the Duck Creek and certainly not later than the Fort Worth limestone, and that it could not have been associated with such Upper Cretaceous species as *Gryphaea vomer*, *Exogyra costata*, and *A. texanus*.

The specific identity of *A. vespertinus* has always been uncertain, and, on account of the nature of the type specimen, which is a poorly preserved large fragment of an adult whorl, will probably never be satisfactorily established. Under the heading *Pervinquieria vespertina*, Adkins (3) says:

> *P. vespertinus* and *P. equidistans* are evidently both *Pervinquieria* of the "trinodose" type, but neither description is sufficiently explicit to decide among the several Texan species of that general group.

In my preliminary studies of Washita ammonites as recorded many years ago in unpublished manuscript the type of *A. vespertinus*, which had been examined by me, was believed to be related to *A. inflatus* and was assigned to *Schloenbachia* in accordance with the custom of the time. *A. leonensis* and several other related forms now known to be distinct species were treated as varieties of *A. vespertinus*. It was in this broad sense that I listed *Schloenbachia vespertina* in the stratigraphic chapter published in Cragin's paper on the paleontology of the Malone Jurassic formation (4).

Many European paleontologists have accepted *A. texanus* as the genotype of *Mortoniceras*. Of these, De Grossouvre and Pervinquière may be cited as examples.

In his discussion of *Mortoniceras* in 1893, A. de Grossouvre (5) considers Meek's description, his designation of *A. vespertinus* as the type, and Gabb's quoted statement that *A. texanus* and *A. vespertinus* "are in all respects identical, Morton's figure being very defective," and then concludes: "Je prends donc, comme type du genre *Mortoniceras*, *Ammonites texanus* de Römer." Pervinquière (6) cites various contradictory interpretations of *A. vespertinus* that have been made by several paleontologists and adds:

> Une conclusion se dégage de ces contradictons: c'est qu'*Amm. vespertinus* est une espèce à rejeter comme insuffisamment définie; je me range entièrement a la proposition, faite par divers auteurs, de prendre comme type du genre *Mortoniceras: Amm. texanus* Roemer, espèce bien caractérisée, que Meek avait d'ailleurs en vue en créant son genre.

So far as the genotype of *Mortoniceras* is concerned, I am in full accord with the two authors last cited. The internal evidence that Meek selected *A. texanus* as the type of *Mortoniceras* is so clear that I can see no justification for applying article 30a[1] of the International Rules of Zoological Nomenclature and opinion 65[2] of the International Commission on Zoological Nomenclature to this case as the basis for displacing the well

[1] "When in the original publication of a genus, one of the species is definitely designated as type, this species shall be accepted as type, regardless of other considerations."

[2] "*Case of a genus based upon erroneously determined species.*—If an author designates a certain species as genotype, it is to be assumed that his determination of the species is correct."

known *A. texanus* as genotype by *A. vespertinus*, a species that a century after its description is still so imperfectly known that it has never been satisfactorily identified. The case is not that of a genus based upon an erroneously determined species. It is rather the erroneous application of an earlier specific name to the well-known species *A. texanus*, which Meek had selected as the genotype of *Mortoniceras*.

Under this interpretation the Upper Cretaceous *texanum* group is the typical section of *Mortoniceras*, and this remains true whether the finally adopted conception of the genus is broad or narrow. In my opinion, therefore, Spath (7) was in error when he stated that because *A. vespertinus* Morton had been shown to be an Albian ammonite related to the "*inflatum-rostratum* group" it becomes "necessary to transfer both family and genus [Mortoniceratidae and *Mortoniceras*] to the Albian forms" and to give a new generic name, *Texanites*, to the Senonian *texanum* group.

REFERENCES

1. MEEK, F. B., A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: *U. S. Geol. Survey Terr.*, vol. 9, p. 448, 1876. (*a*) p. 450.
2. MORTON, S. G., *Synopsis of the organic remains of the Cretaceous group of the United States*, p. 40, pl. 17, fig. 1, 1834.
3. ADKINS, W. S., Handbook of Texas Cretaceous fossils: *Univ. Texas, Bull.* 2838, p. 232, 1928.
4. CRAGIN, F. W., Paleontology of the Malone Jurassic formation of Texas, with stratigraphic notes on Malone Mountain and the surrounding region near Sierra Blanca, Texas, by T. W. Stanton: *U. S. Geol. Survey, Bull.* 266, pp. 23–33, 1905.
5. DE GROSSOUVRE, A., *Recherches sur la craie supérieure*. Pt. 2. Paléontologie. Les ammonites de la craie supérieure, p. 66, 1893.
6. PERVINQUIÈRE, L., *Études de paléontologie tunisienne*. 1. Céphalopodes des terrains secondaires, p. 227, 1907.
7. SPATH, L. F., *Ammonoidea of the Gault*, pt. 9, p. 379, 1932.

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NOTE ON THE CRYSTALLOGRAPHY OF THE ECHINODERM SKELETON

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It is generally known that skeletal parts of echinoderms consist of fine-pored single calcite crystals. This fact is shown by the characteristic crystal optical properties and by the characteristic cleavage of the skeletal parts. Earlier work on the subject is conveniently summarized in W. J. Schmidt's book, *Die Bausteine des Tierkörpers in polarisiertem Lichte* (Bonn, 1924), pp. 92–102. Some more recent work is to be found in several reports by Panning (Zeitschr. f. wiss. Zoologie *132*, 95, 1928, and later papers).

As this type of structure is unusual among both crystals and living organisms, it was thought an X-ray examination of the echinoderm skeleton might prove to be of interest, even if it should only give an independent confirmation of known facts.

Material was obtained from Professor H. L. Clark, of Harvard University, in the form of spines of *Heterocentrotus mammillatus* (Linnaeus) from Hawaii, from which organic matter had been removed. The spines are about 70 mm. in length and 10 mm. in mean diameter. They are not exactly circular in cross section but rather appear to have a single plane of external symmetry passing through their long axis. The density of small fragments as measured by suspension is 2.660 or slightly less than that of calcite, 2.710. As the apparent density measured by submersion in mercury in a graduated cylinder

is about 1.01, the true volume of the solid matter is about 38 percent of the apparent volume of the spine. On ignition a fragment does not disintegrate but retains its original form.

As described by previous writers, the solid matter appears to form a continuous framework. Distances between neighboring structural elements are not uniform, but are estimated to range between 0.01 and 0.10 mm. The refractive indices are nearer to those of calcite than to those of aragonite. The optic axis lies parallel to the long axis of the spine. On immersion in bromnaphthalene the cross section shows a fairly good uniaxial negative interference figure, although, as would be expected, the figure is distinct only in the neighborhood of the centered optic axis. In spite of the brittleness of the material, three cleavage planes may be found in positions approximating those of calcite, but the mat character of these surfaces makes goniometric measurement impossible.

In the X-ray examination, *c*-axis rotation photographs and basal Laue photographs were obtained. All X-ray data point to the definite conclusion that the entire spine is a perfect single calcite crystal with the *c*-axis parallel to the long axis of the spine. None of the three crystallographic symmetry planes, however, appears to coincide with the external symmetry plane of the spine examined—a condition that was also suggested by the cleavage tests. It will be recalled that Laue photographs are quite sensitive to slight imperfections in internal structure. Although for each photograph there were many structural elements in position to diffract (the diameter of the X-ray beam and the thickness of the section each being about 0.5 mm.), the diffraction spots were always sharply defined and showed no indication of twinning or imperfect orientation. In quality the photographs were similar to photographs of calcite made for the purpose of identification and comparison.

Among crystalline mineral species found in living organisms are calcite and aragonite in sea shells, apatite in bones and teeth, and whewellite in some plants. In such organisms the crystalline phase is generally an aggregate of small discrete crystal grains whose orientation is either random or to some extent parallel along one or more crystallographic axes. The skeletal parts of the echinoderm, as we have seen, differ from other organisms in that single large functional units are built around single *continuous* calcite crystals. They thus offer a very special problem in the broad subject of crystal growth. They likewise draw attention again to the often remarked parallelism between the phenomena of biological growth and crystal growth, which two processes here take place concomitantly and *κατ εξοχην*.

The writer is indebted to Professor Charles Palache, Harvard University, for the opportunity to carry out the X-ray study as well as to Professor Clark for the experimental material.

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NOTES ON THE CRANIOMETRY OF *EQUUS SCOTTI* GIDLEY

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The purpose of these notes is to put on record the cranial measurements of a specimen of the Pleistocene horse *Equus scotti* Gidley (1900) discovered at the type locality in the summer of 1936 by a field party from the West Texas State Teachers College. The skeleton is complete except for one hind leg and the caudal vertebrae. Although the osteology of this species is well known, the measurements here recorded, which follow the system proposed by Osborn (1912), may aid in the establishment of typical characters or

in the delimitation of possible variations within the species. Views of the skull are shown in text figures 1–3.

The articulated skeleton was found in a quarry on the Cross MacDaniels ranch near Rock Creek, Briscoe County, Texas, 1,383.3 feet from the east line and 4,119.6 feet from the south line of sec. 213, Block G. & M., Denison & Southeastern Railroad Company survey, at an altitude of 3,221 feet above sea level. This quarry has yielded several other complete or nearly complete skeletons, including the type. They were found in fine consolidated white cross-bedded sand containing granules of calcium carbonate and lying about 30 inches below a 1-inch continuous horizontal stratum of bluish-green clay, which underlies several feet of compact, semi-consolidated gray sand showing no signs of cross-bedding. This bed is overlain by a rather tough layer of green shale, which forms the surface. Gidley (1903) refers to the deposits as the Rock Creek beds, which he considers of fluvial origin and equivalent to the lower Pleistocene Sheridan formation.

Craniometric measurements

	mm.
Vertex length (from median incisive border to middle of occipital crest)	608
Basilar length (from median incisive border to anterior edge of foramen magnum)	549
Frontal width (at posterior borders of orbits)	193
Cephalic index (frontal width ×100 divided by basilar length)	35.1
Facial length (from median incisive border to middle of line connecting posterior border of orbits)	397
Facio-cephalic index (frontal length ×100 divided by basilar length)	72.3
Cranial length (from middle of line connecting posterior borders of orbits to middle of occipital crest)	224
Cranio-cephalic index (cranial length ×100 divided by basilar length)	40.8
Palatal angle line (vertical distance from middle of posterior border of palate to a line connecting median incisive border and foramen magnum)	18
Palato-cranial angle (angle between the basicranial line, taken outside, and basifacial line)	19°
Occiput height (length of perpendicular from middle of occipital crest to base of mandible)	320
Orbital index (vertical diameter of orbit ×100 divided by horizontal diameter)	76.3
Frank's vomer index (distance from posterior border of palate to middle of posterior edge of vomer ×100 divided by distance from same point on vomer to anterior edge of foramen magnum)	52.1
Convexity of fronto-nasal suture (distance from posterior end of internasal suture to middle of line connecting two most posterior points of fronto-nasal suture)	26
Diastema length (I^3-P^2)	100
Muzzle width (at posterior alveolar borders of I^3)	78
Molar-premolar series total length (upper) P^2-M^3	191
Dental index (molar-premolar series total length, upper, ×100 divided by basilar length)	34.7
Molar index (transverse diameter of M^2 ×100 divided by molar-premolar series total length)	1.43

Lower jaws	mm.
Height of horizontal ramus at posterior border of M_3	131
Height of horizontal ramus between P_4 *and* M_1	100
Height of horizontal ramus between P_2 *and* P_3	93
Length of mandible	485
Height of mandible	255
Width of incisive portion	72
Length of series of lower cheek teeth	186
Length of diastema	98

Dental measurements, lower, in millimeters

	P_2	P_3	P_4	M_1	M_2	M_3
Anteroposterior diameter	34	30	32	30	31	30
Transverse diameter	18	18	16	16	16	14

Dental measurements, upper, in millimeters

	P^2	P^3	P^4	M^1	M^2	M^3
Anteroposterior diameter	40	32	31	29	30	27
Transverse diameter	30	31	29	29	28	21

REFERENCES

Gidley, J. W., A new species of Pleistocene horse from the Staked Plains of Texas: *Am. Mus. Nat. History, Bull.* 13, pp. 111–116, 1900.

——— The Fresh-water Tertiary of northwestern Texas: *Am. Mus. Nat. History, Bull.* 19, pp. 617–635, 1903.

Osborn, Henry Fairfield, Craniometry of the Equidae: *Am. Mus. Nat. History, Mem.* 1 n. s., pp. 55–100, 1912.

NOTE: The manuscript of this paper was received by the editor January 26, 1937.

FIG. 1—*Equus scotti* Gidley, side view of skull with mandibles, ×⅓.

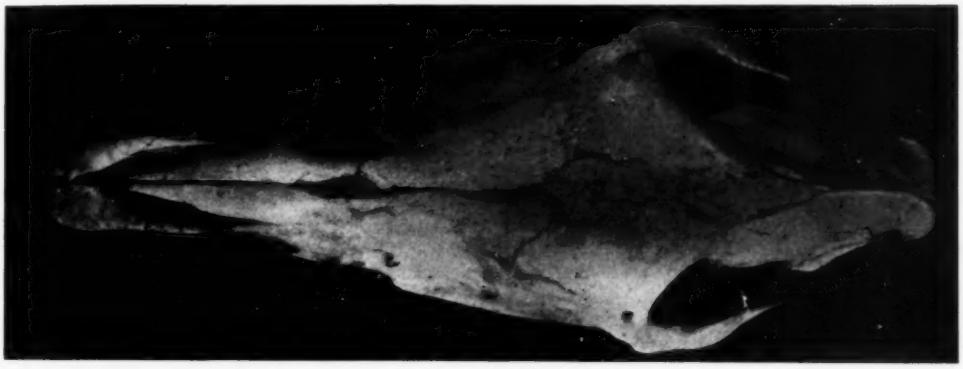

FIG. 2—*Equus scotti* Gidley, dorsal view of skull, ×⅓.

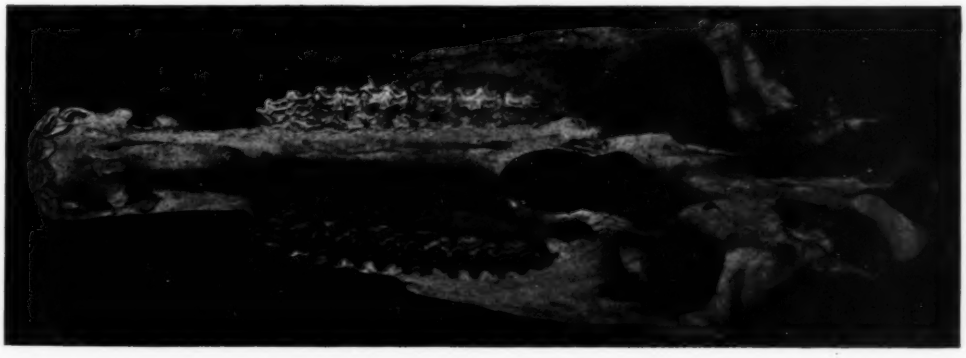

FIG. 3—*Equus scotti* Gidley, ventral view of skull, ×⅓.

A STUDY OF *NEUROPTERIS SCHLEHANI* STUR

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In the course of identifying a group of plant fossils of the Pocahontas, Quinnemont, and Sewell formations of lower Pottsville age from the Beckley Coal Field of West Virginia, collected by Professor W. A. Bendrat of Beckley College, the writer came upon an interesting problem. In accordance with previous usage, a species from the Pocahontas formation was identified as *Neuropteris pocahontas* (D. White), a similar one from the Quinnemont as *N. smithsii* (Lesquereux), and one from the Sewell as *N. schlehani* (Stur). On comparison of the fossils put into these three groups of species, little difference could be found between them other than stratigraphic differences and differences in the shale on which they were found. A careful check was then made on the original descriptions in order to find points of difference between them.

The original description by Stur (1) of *Neuropteris schlehani* reads as follows:

Frond is probably tri- to quadri-pinnate, primary segments are bipinnate, with a striate rachis. Secondary segments are linear with pointed apex, approximately pinnate, almost touching; the tertiary segments have long pedicels, are oblong, have cordate bases, and rounded apex. The lowest are very rarely laterally katadromous lobate, cut into many parts. Tertiary median vein distinct, the nervilles joined under an angle of about 40 degrees, frequently dichotomous twice, rarely three times, arched.

In his plate 11, fig. 7 (my fig. 1) is a representation of a lobing pinnule, with the lobation advanced so far that separate pinnules of the next order are separated off. From the illustration these appear to be distinctly alethopterid.

In 1876 Lesquereux (2) listed a new species, *Neuropteris smithsii*, from the Pottsville of Alabama. In 1879 he figured (3, pl. 13, figs. 1–3) and in 1880 described (3, pp. 106, 107, vol. 1) this new species. The drawings could be correctly labeled *N. schlehani*, so similar are they. The description is as follows:

Frond polypinnate, apparently large; primary divisions lanceolate, open from a broad striate rachis; ultimate pinnae in right angle to a narrow rachis, linear, lanceolate to the apex. Pinnules distant, small, broadly oval, or nearly round, subtruncate, or sub-cordate at the base; terminal pinnule large, oblong, or broadly ovate; middle nerve distinct to near the point, deeply impressed into the thick epidermis; lateral veins sharply marked, curved back to the borders which they reach in a right angle, forking once at the middle, sometimes more from the very base.

Lesquereux states, "I do not know any European species closely allied to this." Though he shows its differences from *N. microphylla*, *N. lindleyana*, and *N. loschii*, he fails to mention *N. schlehani*. He points out that *N. smithsii* is "at once recognized" by its "small, oval, or round, thick leaflets, the terminal pinnules comparatively large, the deep midrib, and the sharply salient veins." Comparing it with *N. schlehani*, we find that "small, oval, round, thick leaflets" are also characteristic of *N. schlehani*, although they are not mentioned in the original description, but are clearly shown in the figure. The drawings also show that the terminal pinnules are comparatively large and that lobation takes place from the lowest of these terminal pinnules. The illustrations of *N. smithsii*, especially Lesquereux's plate 13, fig. 2 (my fig. 2), also show that the newest detached lobes are distinctly alethopterid in appearance. Both *N. schlehani* and *N. smithsii* are characterized by a deep midrib. The chief difference between them seems to be in the nervilles. Those of *N. schlehani* are described as arched, that is, they meet the border in more nearly a 45° angle than a right angle, whereas those of *N. smithsii* are described as meeting the border in a right angle. Is this enough difference to warrant the naming of a new species? Gothan (4) in a discussion of *N. schlehani* lists as one of the so-called species which it includes *N. smithsii*, which he marks with (?).

David White (5) in 1898 described a new

species, *N. pocahontas*. The figures (see my fig. 3) show specimens almost identical with those figured by Stur and Lesquereux. White's description is too long to quote here, but he lists as differences between his species and *N. schlehani*, the following characteristics of the latter:

narrower pinnules, constricted at the base, the midrib well developed, the nervation strongly curved and meeting the margin at nearly a right angle.

In this connection we may refer to White's illustrations. The pinnules are as narrow as those in Stur's drawings, and the pinnules lobing off from them are alethopterid sessile in both cases. Again the difference comes in the nervation. White's description of the nervation of *N. pocahontas* is as follows:

Nervation rather coarse, distinct, regular, usually slightly in relief, more or less flabellate in all except the lowest pinnules, or the lower part of the largest ultimate pinnae. Primary nerve but slightly differentiated in the small pinnules, or of moderate strength, vanishing near the middle in those pinnules of intermediate size, or passing three-fourths the length of the largest pinnules, decurrent in the smallest, nearer the distal sinuses of the laterally unequal pinnules; nervilles very oblique, often nearly equally close in all parts of the lamina, a large portion springing directly from the rachis, especially in the proximal half of the pinnules in all but the very large or the lowest pair of the pinnules, forking twice at a very narrow angle . . . passing with slight or sometimes no curvation in the smaller pinnules, obliquely to the margin.

White also lists the ways in which *N. pocahontas* differs from *N. smithsii*. The former has

generally larger pinnules [not a differentiation of species rank] which are broadly attached [but so were they in the illustrations of *N. smithsii*], more ovate, instead of oval or nearly round, when small [see, however, fig. 3], far less developed median nerves [true], and especially by the much less curved nervilles, which are oblique, springing in part from the rachis, and which seldom meet the border at a right angle [true].

A specimen in the collection studied by the writer, from the Sewell formation and therefore a true *N. schlehani*, showed all stages of lobation on one frond (fig. 4) and showed that the pinnules formed by lobing grade from pure lobes, through alethopterid sessile pinnules, to neuropterid contracted forms. This, it would seem, precludes the differentiation of species on the grounds of shape and mode of attachment of the pinnules.

The differences that remain between their descriptions are entirely those of nervation and are summarized below.

Differences of nervation

	N. schlehani	*N. smithsii*	*N. pocahontas*
Median Vein.	Distinct. Well developed.	Distinct almost to the point.	Primary nerve but slightly differentiated in small and medium-sized pinnules, vanishing near the middle in pinnules of intermediate size and passing three-quarters of the way in largest pinnules.
Lateral Veins.	Strongly curved. Arched.	Curved. Strongly arched.	No curvation in smaller pinnules. Oblique to margin. Some nervilles spring directly from rachis.

The writer, however, examined specimens belonging to these so-called species from the Pocahontas, Quinnemont, and Sewell formations, which, according to their stratigraphic positions should be called respectively *N. pocahontas*, *N. smithsii*, and *N. schlehani*. They were so similar that each fossil slab had to be marked before being taken out of its box to prevent confusion. Upon examination, all of the so-called species showed specimens in which the median nerve continued distinct to the end, others on the same frond in which it appeared almost effaced. On the same rachis of *N. smithsii*, the terminal pinnule showed the nervilles meeting the border at a right angle for most of the border extent,

but near the base, where lobation took place, the angle changed to about 45° (fig. 5). The venation of the small pinnules below, which pinnules had already lobed off, met the border at something approximating a 45° angle except at the center of the lobe borders. A similar phenomenon was seen on specimens of *N. schlehani* and *N. pocahontas* in this collection.

Therefore I believe that all three of these Pottsville so-called species, should be put in one species, *Neuropteris schlehani* Stur. Any variations noted are of subspecific order. A revised description of the species is as follows:

NEUROPTERIS SCHLEHANI Stur

Frond pinnately compound. Rachis entire, tapering, striated. Penultimate pinnae near the top lanceolate, mostly several times longer than broad, narrow to wide, edges for about three-quarters of the total length somewhat parallel, tapering to a wide-angled usually blunt apex. Other forms gradually tapering (more or less elongated triangular) with apex blunt to pointed. Terminal pinnule often tongue-shaped, several times longer than broad, and much longer than the preceding pinnules. Penultimate pinnae towards the base of segment disintegrating through lobation into the pinnules. Ultimate pinnae near base of segment usually typically neuropterid contracted, the lowest sometimes distinctly pediceled. The higher ones more or less alethopterid sessile, grading into the lobes of the penultimate pinnae at the beginning of lobation. Usually oval to rotund, considerably smaller than the terminal pinnule. In pieces from the lower portion of the frond, therefore with a thick rachis, often only the lowest pair of penultimate pinnae have lobed-off pinnules. Finer specimens, from the upper portions of the frond, are much more lobed. On the penultimate pinnae or the terminal pinnule of the ultimate pinnae, the middle vein is distinct almost to the top, at least three-quarters of the way. Lateral veins are forked once or twice, somewhat distant, quite distinct. Curve strongly and in the penultimate pinnae reach the margin at almost a right angle, except at the lower edge, where lobing has taken place. Many ultimate pinnae show no distinct midrib or have it effaced above the middle. Sometimes one or two veins of the ultimate pinnae spring directly from the rachis.

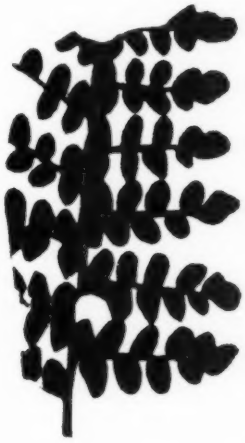
REFERENCES

1. STUR, DIONYSIUS, Die Culm-Flora: *K.-k. geol. Reichsanstalt*, Abh., Band 8, Heft 2, Wien, p. 183, pl. 11, figs. 7, 8a, 8b, 8v, 1875–77.
2. LESQUEREUX, LEO, Partial list of coal plants from the Alabama fields and discussion of the geological positions of several seams: *Alabama Geol. Survey, Rept. Prog. 1875*, p. 76, 1876.
3. ——— Description of the coal flora of the Carboniferous formation in Pennsylvania and throughout the United States: *Pennsylvania 2d Geol. Survey, Rept. P.*, 3 vols. and atlas, 1879–84.
4. GOTHAN, WALTER, in Potonie, H., Abbildungen und Beschreibungen fossiler Pflanzen-Reste, Lief. V, Leaflet 100: *K. Preuss. Geol. Landesanst*, 1907.
5. WHITE, DAVID, Fossil floras of the Pottsville formation in the southern anthracite coal field (Pennsylvania): *U. S. Geol. Survey, 20th Ann. Rept.*, Pt. 2, pp. 888–893, pl. 190, figs. 7 and 8, pl. 191, figs. 1–4, 5, 5a, 1899.

NOTE: The manuscript of this paper was recived by the editor May 1, 1937.

FIGS. 1—*Neuropteris schlehani* Stur. (Fig. 7, plate ii, Die Culm-Flora.)
2—*Neuropteris smithsii* Lesquereux. (Fig. 2, plate 13, Atlas to the coal flora of Pennsylvania.)
3—*Neuropteris pocahontas* White. (Fig. 5, plate 191, Fossil flora of the Pottsville formation.)
4, 4*a*—Photograph and line drawing made from the photograph of a specimen of *Neuropteris schlehani* showing stages in lobation.
5, 5*a*—Photograph (×5) and line drawing made from the photograph of *Neuropteris schlehani*, showing angles made by secondaries with the border.

1



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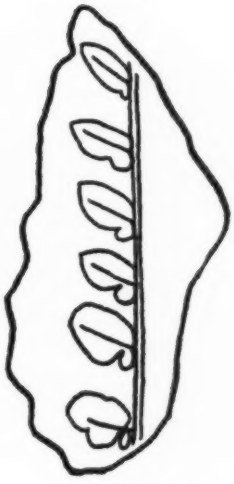

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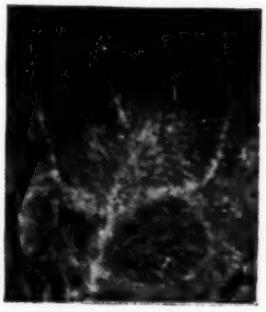

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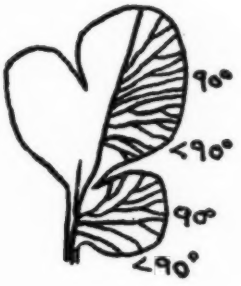

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FIGURES 1–5

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BUCKMAN, S. S., Died Feb. 26, 1929.
CANU, FERDINAND. Died Feb. 12, 1932.
COBBOLD, EDGAR STERLING. Died Nov. 20, 1936.
DEPÉRET, PROF. CHARLES. Died May 17, 1929.
KIAER, PROF. JOHAN. Died Oct. 31, 1931.
KOKEN, E. Died Nov. 24, 1912.
NATHORST, DR. A. C. Died Jan. 20, 1921.
POMPECKJ, DR. J. F. Died July 8, 1930.
WOODWARD, DR. H. Died Sept. 6, 1921.

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*ALDRICH, TRUMAN H. Died April 28, 1932.
*AMI, HENRY M. Died Jan. 4, 1931.
ARMSTRONG, EDWIN J. Died Jan. 21, 1929.
*BARRELL, JOSEPH. Died May 4, 1919.
BELANSKI, CHARLES H. Died Apr. 30, 1929.
BENSLEY, B. A. Died Jan. 20, 1934.
BILLINGS, W. R. Died Mar. 1, 1920.
BOSTWICK, THOMAS A. Died Apr. 1923.
*BROWN, T. C. Died Feb. 28, 1934.
*CALVIN, SAMUEL. Died Apr. 17, 1911.
*CLARK, WM. B. Died July 27, 1917.
*CLARKE, JOHN M. Died May 29, 1925.
*CLELAND, HERDMAN F. Died Jan. 24, 1935.
*CROOK, A. R. Died May 30, 1930.
CROZEL, GEORGE. Died Oct., 1921.
DALL, W. H. Died Mar. 27, 1927.
*DEAN, BASHFORD. Died Dec. 6, 1928.
*DERBY, ORVILLE A. Died Nov. 27, 1915.
DOUGLASS, EARL. Died Jan. 13, 1931.
*EASTMAN, CHAS. R. Died Sept. 27, 1918.
*FOERSTE, AUGUST F. Died Apr. 23, 1936.
*FONTAINE, WM. M. Died Apr. 30, 1913.
GIBB, HUGH. Died Feb. 28, 1932.
*GIDLEY, JAMES WM. Died Sept. 26, 1931.
GILL, THEODORE N. Died Sept. 25, 1914.
GORDON, ROBERT H. Died May 10, 1910.
HAMLIN, HOMER. Died July, 1920.
HARPER, GEORGE W. Died Aug. 19, 1918.
HAWVER, J. C. Died May 15, 1914.
*HAY, O. P. Died Nov. 2, 1930.
*HOLLAND, WM. J. Died Dec. 15, 1932.
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LEE, WILLIS T. Died June 17, 1926.
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ERRATUM

The title of plate 33, vol. 11, should be "Girty, Upper Carboniferous Gastropods" instead of "Girty, Permian Gastropods."